HEATHKIT® MANUAL

for the

10 MHz, DUAL-TRACE OSCILLOSCOPE
Model IO-4550

OPERATION 595-1850-01

HEATH COMPANY • BENTON HARBOR, MICHIGAN

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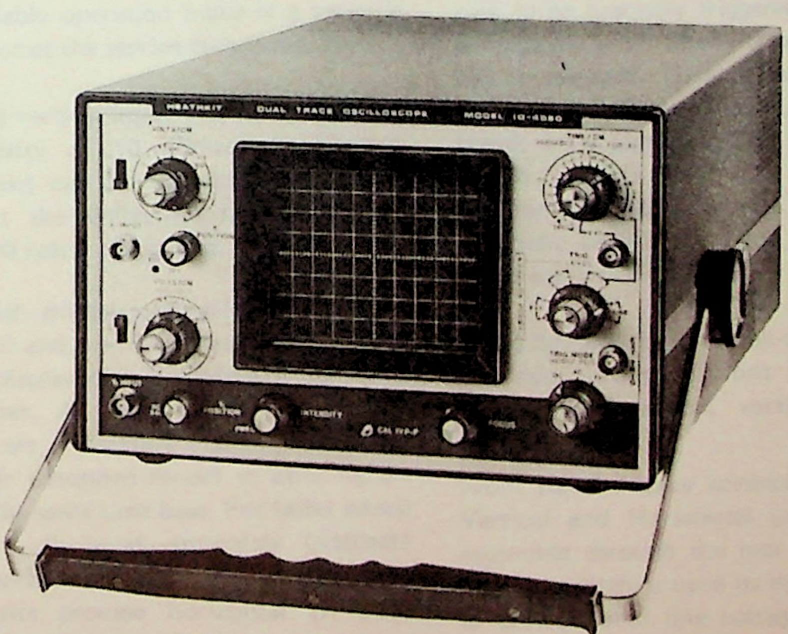

Printed in the United States of America

HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

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INTRODUCTION

This Oscilloscope is a portable, triggered-sweep, dual-trace, DC-to-10 MHz, laboratory-grade instrument. Outstanding features such as the fast vertical rise time, good trace brightness, and the high input sensitivity make the Oscilloscope ideal for the wide range of measurements typically encountered in electronics, development laboratories, and scientific research. In addition, the rugged construction and dependable operation make it a versatile tool for either the hobbyist or the service technician.

Each of the two identical vertical input channels provides a maximum signal sensitivity of 10 millivolts/centimeter. Their attenuator networks can be switched through 11 calibrated ranges to set the deflection factor from 10 millivolts/centimeter to 20 volts/ centimeter.

Several modes of signal display are selected by each channel's position control and the Time Base switch. Either or both channels can be displayed as a function of time or as a function of each other. At slower sweep speeds, the vertical channel signals are alternately displayed at a 200 kHz (approximately) rate (chopped mode) so both signals appear as a function of the same time base. For faster sweep speeds, both signals are displayed alternately (alternate mode) on successive sweeps. During X-Y operation, the Channel Y1 (X) circuits provide horizontal (X axis) deflection and the Channel Y2 (Y) circuits provide vertical (Y axis) deflection.

Calibrated time-base ranges from .2 seconds/centimeter to .2 microseconds/centimeter are readily switched in a 1-, 2-, 5-step sequence. A control on the Time Base switch provides variable sweep speeds between switch positions. Any sweep speed can be expanded 5 times when the X5 control is pulled out, giving a maximum sweep speed of 40 nanoseconds/centimeter.

The Trigger Select switch and Level control allow the time base to be precisely triggered at any point along the positive or negative slope of the trigger signal. Various trigger signals can be selected. These include a sample of Channel Y1 or Channel Y2 input signals, an externally applied trigger signal, or a sample of the line voltage. The Trigger Mode switch controls the trigger input bandpass. A special TV position cuts off unwanted high frequency signals. This is especially useful when you want to trigger on TV vertical frame signals.

A calibrated 1-volt peak-to-peak square wave signal is provided through a front panel connector, allowing easy probe compensation, vertical amplifier calibration, and comparison.

Front panel display controls include Intensity, Focus, and Vertical and Horizontal position. An additional control, accessible through the rear panel, adjusts Astigmatism. An internal switch is used to match the regulated power supply to conventional line voltages from 105 volts to 260 volts AC.

Thus, this Oscilloscope combines the most desirable features required for precise measurement and display, while its solid-state circuitry provides excellent sensitivity, stability, and versatility.

SPECIFICATIONS

VERTICAL

Deflection Factor:

Sensitivity	10 mV/cm to 20 V/cm.
Attenuator	11 steps in 1-2-5 sequence.
Variable	Continuous between steps to approximately 60 V/cm.
Accuracy	Within 3% (10°C to 40°C), referred to 0.2 V/cm.

Vertical Response:

DC Coupling	DC to 10 MHz (–3 dB) at 6 cm.
AC Coupling	2 Hz to 10 MHz (–3 dB) at 6 cm.
Rise Time	35 ns.
Overshoot	Less than 5%.

Vertical Input:

Impedance	1 MΩ shunted by 38 pF.
Maximum Input	400 V peak combined AC and DC.
Connector	BNC.

Vertical Modes:

Single	Y1 or Y2 selected by POSITION control.
Dual	Chopped (200 kHz) or alternate automatically selected by TIME/CM switch.

HORIZONTAL

Time Base:

Ramp	0.2 s/cm to 200 ns/cm.
Positions	19 steps in 1-2-5 sequence.
Variable	Continuous between ranges to approximately 0.6 s/cm.
Accuracy	Within 3% (20°C to 30°C) 5% (10°C to 40°C). Referenced to 1 ms/cm at 25°C.
Magnifier	X5 (adds additional 2% to sweep accuracy.)

External:

Sensitivity	0.1 V/cm (approximately).
Impedance	100 kΩ (approximately).
Polarity	Positive input causes right-hand deflection.
Frequency Response	DC to 1 MHz (–3 dB).
Connector	BNC.

TRIGGER

Internal:

Automatic	Adjustable over 10 divisions.
Normal	Adjustable over 10 divisions.
Slope Selection	+ or –.

Sensitivity/Bandwidth

MODE	1 cm	1.5 cm
DC: auto	DC to 20 MHz	DC to 20 MHz
norm	DC to 20 MHz	DC to 20 MHz
AC: auto	20 Hz to 20 MHz	20 Hz to 20 MHz
norm	20 Hz to 20 MHz	20 Hz to 20 MHz
TV: auto	20 Hz to 1 kHz	15 Hz to 2 kHz
norm	20 Hz to 1 kHz	15 Hz to 2 kHz

External:

Automatic . . . . Adjustable over 0.8 V.

Normal . . . . Adjustable over 0.8 V.

Slope Selection . . . . + or –.

Sensitivity/Bandwidth

MODE	0.5 V	1 V
DC: auto	DC to 20 MHz	DC to 20 MHz
norm	DC to 20 MHz	DC to 20 MHz
AC: auto	20 Hz to 20 MHz	20 Hz to 20 MHz
norm	20 Hz to 20 MHz	20 Hz to 20 MHz
TV: auto	20 Hz to 1 kHz	20 Hz to 2 kHz
norm	20 Hz to 1 kHz	20 Hz to 2 kHz

Impedance . . . . 1 MΩ shunted by 40 pF.

Connector . . . . BNC

X-Y

Y Channel	Same as Vertical.
X Channel	Same as Vertical, except response is limited to 1 MHz.
Phase Shift	Less than 8° at 100 kHz.

GENERAL

CRT:	
Type	5" round, mono accelerator.
Acceleration Potential	1.8 kV regulated.
Phosphor	P–31.
Graticule	8 by 10 cm.
Power:	
Voltage Range	105 to 130 VAC/210 to 260 VAC switch selected, 70 watts at 120 VAC (240 VAC).
Internal Supplies	Fully regulated.
Operating Temperature Range	10°C to 40°C.
Dimensions	Height: 6.937 in. (17.6 cm). Width: 12.875 in. (32. 7 cm). Length: 19.25 in. (48.9), without handle. Length: 21.5 in. (54.6 cm), with handle.
Weight	22 lbs. (10 kg).

OPERATION

This section of the Manual explains the function of each control, switch, and connector; gives a preset for each control and switch; describes how to correlate between time/cm and frequency; and provides operational examples.

ALTERNATE PRIMARY VOLTAGES

In the United States 120 VAC line voltage is most often used, while in other countries 240 VAC line voltage is more common. If your line voltage is consistently below 115 volts (or below 230 volts if you intend to operate the Oscilloscope on 240 volts), perform the following steps. Otherwise, proceed to "Control Functions." NOTE: Electrical regulations in some areas require a special line cord and/or plug for 240-volt operation. Replace them if necessary.

( ) Remove the top and bottom covers of the Oscilloscope.

If your line voltage is consistently below 115 (or 230) volts:

( ) Shift the NOR/LOW switch to the LOW position. (See Figure 23 in the "Illustration Booklet").

If you intend to operate your Oscilloscope on 240 volts:

( ) Shift the 120/240 slide switch to the 240 position. This switch is located on top of the rear subchassis, between the CRT and power transformer.

( ) Remove the 1-ampere slow-blow fuse and install the 1/2-ampere slow-blow fuse supplied with this instrument. The fuseholder is located on the bottom side of the rear subpanel.

( ) Reinstall the top and bottom covers. Be sure the cover edges fit into the side rail grooves before you tighten the two thumbscrews.

CONTROL FUNCTIONS

NOTE: Some illustrations that are too large for the Operation Manual are included in a separate "Illustration Booklet." Use these large illustrations when a step refers to the "Illustration Booklet."

Refer to Figure 1 (in the "Illustration Booklet") for the location and explanation of the front panel controls and switches.

PRESETTING CONTROLS

1. Set the front panel controls and switches as follows:

INTENSITY	Fully counterclockwise (PWR OFF)
FOCUS	Center of rotation
HORIZ POS	Center of rotation
TRIG MODE	AC
TIME/CM	.1mS
VARIABLE-Pull for X5	Fully clockwise (CAL) and pushed in (X1)
TRIG	Y1, + (plus)
LEVEL	Center of rotation and pushed in (AUTO)
Y1:	
POSITION	Center of rotation
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
INPUT switch	GND
Y2:	
POSITION	Fully counterclockwise (OFF)
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
INPUT switch	GND

The following procedure will prepare the Oscilloscope for operation in any mode, and may be used at any time to check the basic instrument operation.

2. Connect the line cord to an AC power source.

CAUTION: Do not permit a bright dot to remain on the face of the cathode ray tube for a prolonged period of time; a dot will burn the phosphors and leave a permanent image in the face of the CRT.

3. Turn the INTENSITY control clockwise 1/3 of its rotation.

4. Allow a minute or two for the instrument to warm up.

5. Slowly adjust the Y1 POSITION control and the HORIZ POS control to center the trace on the screen.

6. Adjust the INTENSITY control to obtain a trace just bright enough for your room lighting conditions.

7. Adjust the FOCUS control for the finest and sharpest trace.

8. Adjust the HORIZ POS control so the trace starts at the left edge of the graticule.

Your Oscilloscope is now prepared for operation in the modes described in the "Operational Examples" section.

DC BALANCE (DC BAL)

The highly sensitive vertical amplifier input circuits in this Oscilloscope, as in other sensitive equipment, may exhibit an occasional unbalance caused by aging components and temperature effects. Even though the DC BAL (balance) control is not considered to be an operating control, you should make it a habit to check the DC balance periodically and readjust it when necessary. You will need a small screwdriver to make this adjustment through the small hole in the front panel.

To check the DC balance of either channel, set the input switch (AC-GND-DC) to ground (GND) and obtain a trace on the CRT. Turn the VOLTS/CM VARIABLE gain control from fully clockwise to fully counterclockwise. If the trace moves vertically, readjust the DC balance as follows:

1. Turn the VOLTS/CM switch to the 10 mV position.
2. Turn the VARIABLE gain control fully counterclockwise.
3. Center the trace on the screen.
4. Turn the VARIABLE gain control fully clockwise to the CAL position.
5. Adjust the DC BAL control to return the trace to the centerline.
6. Repeat steps 2 through 5 until the trace does not move when the VARIABLE gain control is turned.

NOTE: If the trace does not move as the VARIABLE gain control is turned, but moves when the VOLTS/CM switch is changed, perform the "Vertical Amplifier Balance" on Page 27.

NORMAL OPERATING CHARACTERISTICS

The following information is provided to help answer possible questions you may have about the operation of your Oscilloscope.

Several minutes may be required for the trace to stabilize when the Oscilloscope is first turned on, especially on the more sensitive voltage ranges.

Random noise on the input signal may cause false triggering, especially on the most sensitive voltage ranges.

A baseline will automatically appear after a short pause when the trigger LEVEL control is pushed in to the AUTO position or when the input signal is disconnected when automatic triggering is used.

In the EXT horizontal mode, the horizontal position of the trace may change with different horizontal driving resistance.

USING A 10 MILLIVOLT OSCILLOSCOPE

When you use an Oscilloscope as sensitive as this, you must use special care to make reliable measurements. Keep the following points in mind when you measure very low level signals.

Placement of the ground clip may be critical if the signal source ground carries an appreciable current. Voltage differences of several millivolts from one side of a chassis or ground foil to the other are common. Place the ground clip at the point that gives the least error. This is usually nearest the signal source. You may have to move the ground clip when you measure different points.

Stray 60 Hz pickup may be hard to eliminate, especially in high impedance circuits. Be sure to use shielded test cables. Shield the signal source if necessary.

Wideband measurements in the millivolt region are more difficult because of the inherent noise (shot noise and thermal noise) generated by electronic components. This may appear as a widening of the baseline or the baseline appearing out of focus. Noise on the baseline that appears as "hash" or "spikes" may be caused by the electromagnetic pickup of man-made noise such as ignition noise, appliance noise, etc. Noise of any kind may cause erratic triggering.

OPERATIONAL EXAMPLES

This section of the Manual gives several examples of how to use the Oscilloscope in its different modes of operation. These examples will help you become familiar with the controls, especially the sweep and triggering controls, and with dual-trace operation.

EXAMPLE 1

Triggering the Sweep on the + or – Slope of a Waveform

Signal source: Sine wave generator capable of a 1 kHz, 1 volt rms signal.

Be sure all controls and switches are in the positions described in "Presetting Controls" (Page 9). Do not change any of these settings unless you are directed to do so in a step. Connect the Y1 vertical input cable to the sine-wave generator output. Place the Y1 INPUT switch (AC-GND-DC) in the AC position and set the VOLTS/CM switch to 500 mV. Be sure the VARIABLE control is fully clockwise.

Turn the TIME/CM switch to the .1 mS position. (The VARIABLE–X5 control should be fully clockwise and pushed in.)

Turn the LEVEL control to the 12 o'clock position and be sure it is pushed in. Then turn it slightly each way from the center and observe the leading (left-hand) edge of the waveform. Note that the LEVEL control sets the point on the waveform when the sweep starts. See Figure 2.

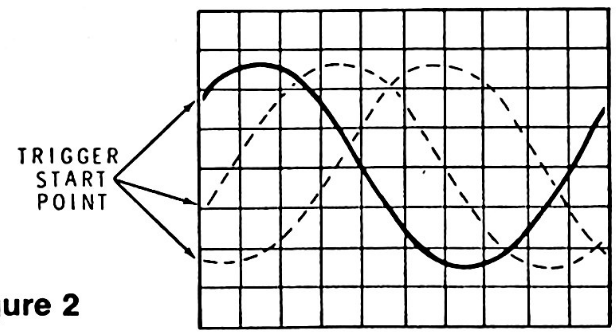


Figure 2

Change the TRIG switch to Y1 minus (–) and note that triggering now starts on the downward or negative slope of the waveform as in Figure 3. Vary the LEVEL control to move the starting point up or down on the slope.

Return the TRIG switch to the Y1 plus (+) position and the LEVEL control to center and pulled out. Then set the INPUT switch to its center (GND) position and the trace will disappear.

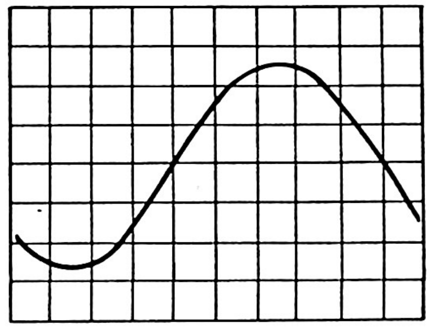
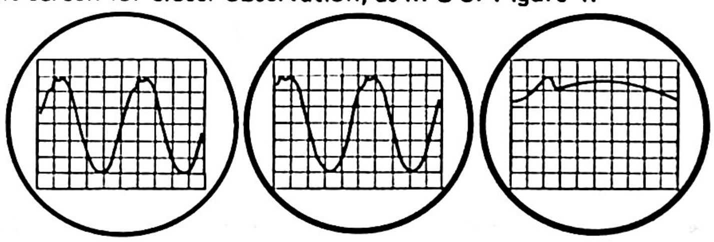


Figure 3

The waveform will appear only when the INPUT switch is in either the AC or DC position. Leave the Y1 INPUT switch in the AC position. A baseline will automatically appear when the INPUT switch is in the GND position and the LEVEL control is pushed in.

Now, assume that you want to examine the "spike" on waveform A of Figure 4. First, adjust the LEVEL control so the sweep starts just before the spike, as in B of Figure 4. Then decrease the time required for one complete sweep by changing the position of the TIME/CM and/or the X5 switch. The X5 expands the sweep around the center two centimeters. The spike is now spread across a large area of the screen for closer observation, as in C of Figure 4.



A B C

Figure 4

Read the TIME/CM and X5 switch settings to determine the duration of the spike. This feature is also useful to observe distortion in circuits using square wave signals.

The X5 function causes the beam to theoretically travel five times further. Thus, to sweep across one centimeter, the trace must now travel this distance in 1/5 the time specified by the TIME/CM switch. When the X5 magnifier is used (pulled out), the true sweep speed is found as follows:

$$\text{True time/cm} = \frac{\text{Time/cm}}{5} \text{ OR Time/cm (x) .2}$$

Example: Time/cm switch setting = 2 mS/cm

X5 switch pulled out.

$$\text{True time/cm} = \frac{2 \text{ mS}}{5} = 0.4 \text{ mS/cm}$$

EXAMPLE 2

Normal or Automatic Triggering

The AUTO mode (automatic triggering) provides a base or reference line without the presence of a vertical input signal. This line is used as a reference point, especially for DC measurements.

With the controls and switches set as they were at the conclusion of Example 1, and with a waveform of the 1 kHz sine wave signal on the CRT, push in the LEVEL control to the AUTO position. The trace will appear as one complete cycle.

Make sure the TIME/CM switch is in the .1 mS position and the VARIABLE control is fully clockwise and pushed in.

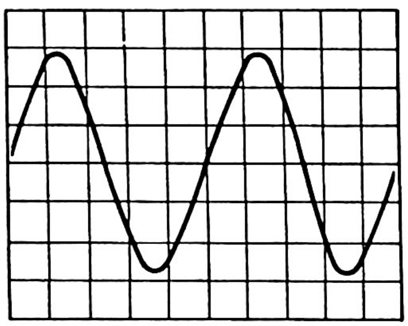


Figure 5

Slowly increase your signal generator frequency to 2 kHz and note that the display on the CRT remains locked in. At 2 kHz, two complete cycles of the input signal will be displayed as in Figure 5.

XAMPLE 3

race Operation

ource: Sine wave — square wave generator capable of e, simultaneous, sine wave and square wave output, 1

ine wave signal to the Y1 INPUT and the to the Y2 INPUT.

Y2 VOLTS/CM switches at 1V and AC; then set the following switches

1, plus (+)
C
enter of rotation and
ushed in (AUTO)
mS

Adjust the Y1 and Y2 POSITION controls so the two waveforms are separated on the CRT. The display will be similar to that shown in Figure 6.

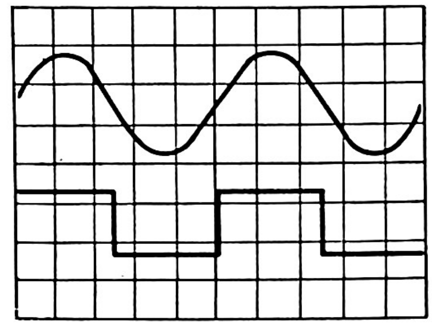


Figure 6

NOTE: Either channel can be turned off by turning the respective POSITION control fully counterclockwise to the detent (OFF) position.

Turn the LEVEL control so triggering occurs at the peak of the sine wave as in Figure 7. Note that this is at the midpoint of the positive portion of the square wave.

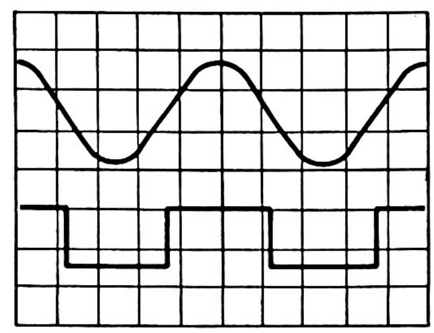


Figure 7

Return the LEVEL control to the center of rotation and the waveforms will again appear in their generated phase relationship.

EXAMPLE 4

X-Y Mode Operation

With the TIME/CM switch in the X-Y position, and the TRIG in Y2, Y2 (Y) signals produce vertical deflection while Y1 (X) signals produce horizontal deflection. In the X-Y mode, the Y1 (X) controls and switches affect the horizontal display. Adjust the HORIZ POS control so the Y1 (X) POSITION control will move the spot off the screen in both directions.

Trapezoidal and Lissajous patterns that are useful in studying modulation characteristics, and frequency and phase comparisons, result from applying separate signals to the Y1 (X) and Y2 (Y) inputs in the X-Y mode.

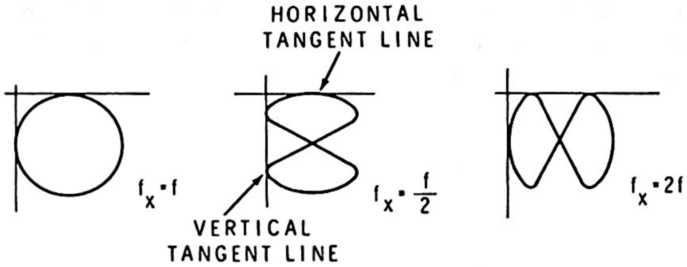


Figure 8

Typical Lissajous patterns are shown in Figure 8. The pattern depends upon the relative amplitudes, frequencies, and phase of the two voltages. The frequency ratio can be figured from the formula:

$$f_x = \frac{Th\ (f)}{T_v}$$

Where f_x is the unknown frequency, Th is the number of loops which touch the horizontal tangent line; Tv is the number of loops which touch the vertical tangent line; f is the known frequency.

When using Lissajous figures, it is good practice to have the figure rotating slowly rather than remain stationary. This eliminates the possibility of an error in counting the tangent points. If the pattern is stationary, a double image may be formed. In such cases, the end of the trace should be counted as one-half a tangent point rather than a full point. This condition may occur when neither frequency can be varied.

Example 5

Phase Measurements (X-Y Function)

It is sometimes necessary to determine the phase relationship between two AC voltages of the same frequency. This can be accomplished quite easily by applying one of the voltages to the horizontal input and the other voltage to the vertical input. The phase relationship can be estimated from Figure 9.

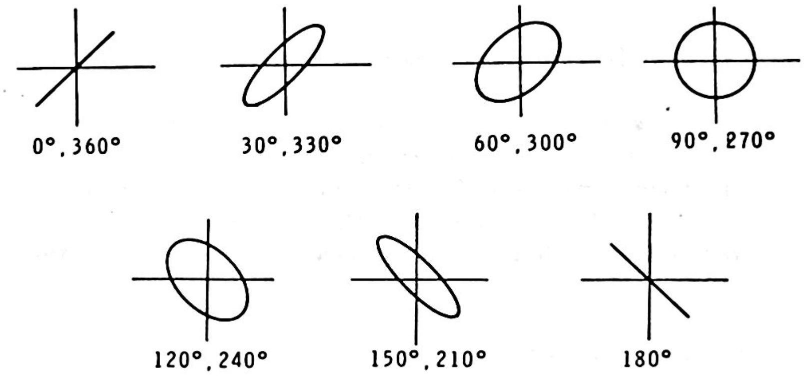


Figure 9

NOTE: For proper displays, the horizontal amplifier gain must be set to equal the vertical amplifier gain.

To calculate the phase relationship, use the following formula:

$$\sin\theta = \frac{A}{B}$$, where θ is the phase angle.

As shown in Figure 10, distance A is measured from the X axis to the intercept point of the trace and the Y axis. The distance to B represents the height of the pattern above the X axis. The axes of the ellipse must pass through the point 0.

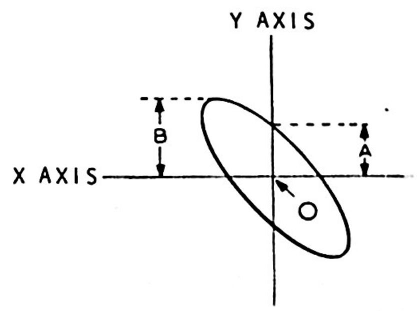


Figure 10

Example 6

TIME/CM-To-Frequency Correlation

Eleven vertical and nine horizontal lines on the graticule, spaced 1 centimeter apart, permit the measurement of displayed waveforms. The short markers on the centerlines are spaced 2 millimeters apart. Use the following formula to determine the frequency of a waveform displayed on the CRT.

TIME/CM switch*
setting in seconds
per cm.

$$\times \frac{1}{\text{MAGNIFIER}}$$

$$\times \begin{matrix}\text{Centimeters for 1}\\ \text{cycle of unknown}\\ \text{frequency}\end{matrix} = \begin{matrix}\text{Period of}\\ \text{unknown}\\ \text{frequency.}\end{matrix}$$

$$\text{and, } \frac{1}{\text{Period}} = \text{Frequency}$$

EXAMPLE: If one cycle of a waveform measures 2 cm on the graticule, with the TIME/CM switch at 1 mS and the X5 switch pulled out, then —

$$.001^{**} \times \frac{1}{5} \times 2 = .0004, \text{ and } \frac{1}{.0004} = 2500 \text{ Hz.}$$

NOTES:

*The VARIABLE —X5 control must be fully clockwise to use the calibrated TIME/CM switch settings in this formula.

**1 millisecond = .001 second; 1 microsecond = .000001 second.

When the X5 switch is pulled out, the sweep travels 5 times further (theoretically), which makes the sweep time shorten by a factor of 5.

THEORY OF OPERATION

The dual-trace capability of this Oscilloscope allows two different signals to be displayed on a conventional CRT (cathode ray tube) that has only one set of vertical deflection plates. Two identical vertical preamplifier circuits, a switching circuit, and a vertical deflection amplifier make this possible. Each vertical preamplifier circuit attenuates its input signal by a known factor, amplifies it to a usable level, and provides the necessary positioning bias. The switching circuit (a diode-type switch), which is automatically controlled by the display control circuit, alternately allows the output signals from the two preamplifier circuits to pass to the vertical deflection amplifier. The vertical signal, a composite of both input signals, is amplified further by the vertical deflection amplifier before it is applied to the vertical deflection plates of the CRT. The signal at the vertical deflection plates, which produces the display on the CRT screen, thus represents both input signals as one "time-shared" signal.

The horizontal portion of the trace displayed on the CRT screen is produced by the sweep and trigger circuits in conjunction with the horizontal deflection amplifier. The sweep circuit produces the linear signal (ramp) used to sweep the electron beam across the CRT screen from left to right at a constant rate. This circuit is switch controlled (by the TIME/CM switch) to provide nineteen accurate sweep rates needed to view and measure almost all input signals. This circuit must be triggered either by a portion of one of the vertical input signals, by an external signal, or by a portion of the line frequency signal.

In the absence of a trigger signal, an automatic baseline circuit causes the sweep circuits to operate while in the automatic mode. This ensures that, even though no signal is applied, a reference baseline (trace) will appear on the CRT screen. The sweep signal is coupled to the horizontal deflection amplifier where it is amplified before being applied to the horizontal deflection plates of the CRT. Other circuits within the horizontal amplifier also provide the necessary positioning bias.

At the end of each horizontal sweep, the blanking circuits (which are triggered by the sweep circuits) turn the trace off (blank it). This prevents a line (retrace) from being displayed as the electron beam returns to the left side of the CRT screen to start a new trace.

Regulated power supply circuits ensure overall accuracy as well as excellent control of the electron beam size and intensity.

CIRCUIT DESCRIPTION

Refer to the Block Diagram and the Schematic Diagram (in the "Illustration Booklet") as you read this "Circuit Description."

Components are numbered in the following groups:

1-99 Parts on the chassis.

100-199 Parts on the vertical circuit board.

200-299 Parts on the horizontal circuit board.

300-399 Parts on the low voltage circuit board.

400-499 Parts on the high voltage circuit board.

VERTICAL

The vertical preamplifier consists of two identical circuits: One for Channel Y1 and the other for Channel Y2. Components in the Channel Y1 vertical preamplifier circuit are designated by a –1 suffix, while those in the Channel Y2 vertical preamplifier are designated by a –2 suffix. (For example: A Channel Y1 divider resistor is R101-1, while the same divider resistor in Channel Y2 is R101-2). Components without a suffix do not relate to a specific channel. Since both channels are identical, only Channel Y1 is described in this "Circuit Description."

INPUT CIRCUIT

When Y1 input switch SW1 (AC-GND-DC) is in the DC position, a signal applied to the Y1 input connector is coupled to the input attenuator. When the Y1 input switch is in the AC position, the signal is coupled through capacitor C1, which passes only AC signals. This permits an AC signal superimposed on a DC potential to be seen without the DC component being displayed. The GND position of this switch disconnects the input signal and grounds the attenuator input. This allows the trace to be adjusted to a zero reference without disconnecting the test leads from the circuit under test.

Because the second (Q109-1/Q110-1) and vertical deflection amplifiers (Q111-Q114), which will be discussed later, operate at a fixed gain, any signal applied to them must be within a usable range (approximately 80 mV/cm). Therefore, the primary purpose of the vertical input circuits is to reduce or increase the input signal by a known factor to this usable level.

The vertical input circuit basically consists of an attenuator, an input follower, and a switched-gain amplifier. These circuits function together, through the VOLTS/CM switch, to provide the total desired attenuation or gain. The attenuator obtains its four attenuation factors (1, 10, 100, and 1000) from four divider networks (resistors R101-1 thru R106-1, and capacitors C101-1, C103-1, C104-1, C106-1, C107-1, and C109-1). At DC and low AC frequencies, the resistive dividers reduce the input signal level; while at higher frequencies, attenuation is determined by the resistor-capacitor (RC) networks.

Caps in the Attenuator network

Trimmer capacitors C101-1, C104-1, and C107-1 are used to adjust the capacitor division ratio to match the resistor ratio. Trimmer capacitors C102-1, C105-1, C108-1, and C111-1 are adjusted during calibration to make the input capacitance of the Oscilloscope equal on all positions of the VOLTS/CM switch. This is essential when an attenuation probe (usually X10) is used.

Input Follower

The input follower circuit consists of a FET (field-effect-transistor) source follower, DC current source, and an impedance translator. The attenuated input signal is coupled through resistors R108-1 and R109-1, and capacitor C112-1 to the gate of FET source follower, Q101-1. Capacitor C112-1 forms a high frequency path around R109-1 for improved frequency response. Input protection is provided by two FET's (D101-1 and D102-1) wired as reverse biased diodes. They are connected to the plus (+), and minus (–) 15-volt supplies. Thus, if the input signal, after the input attenuator, exceeds 15 volts the FET's become forward biased and clamp the signal to within a diode drop of 15 volts. This prevents damage to Q101-1 if the VOLTS/CM switch is in a low range, and a high potential is applied to the input.

Transistor Q101-1 provides the high input impedance necessary to prevent attenuator loading and a low output impedance to drive emitter follower transistors Q103-1 and Q104-1. To compensate for the DC voltage present at the source of Q101-1 when no signal is applied, FET Q102-1 forms a DC current source. DC BAL control R5 is adjusted so that the current supplied is sufficient to produce a zero output at the source of Q101-1 for a zero input at the gate of Q101-1. The circuit formed by diodes D103-1 and D104-1, and transistors Q103-1 and Q104-1 acts as an impedance translator. It reduces the output impedance of the input follower to approximately 50 ohms. The output of the input follower is coupled to the switched-gain amplifier.

This switched-gain amplifier is formed by transistors Q105-1 and Q106-1 to provide a double-ended output from a single-ended input signal. A relatively constant current is supplied through resistor R119-1 to the amplifier, so that an increase in current through Q105-1 will cause a corresponding decrease in current through Q106-1. Thus, as Q105-1 amplifies the input signal, Q106-1 produces an equal but opposite signal. This creates a push-pull effect on the signal, which is amplified in the following stages to drive the vertical deflection plates of the CRT. Front panel VARIABLE control R128-1 adjusts the gain of the amplifier when it is turned from its detented CAL (fully clockwise) position.

Two switch-selected RC networks reduce the gain of this switched-gain amplifier from 8 to 4 and 1.6. Table I shows how the VOLTS/CM switch selects the various attenuation factors and gains of the switched-gain amplifier to provide the desired total gain. STEP BALANCE control R124-1 adjusts the collector currents of Q105-1 and Q106-1 so that the CRT trace does not shift when the gain (VOLTS/CM switch) is switched.

TABLE I

VOLTS/CM POSITION	ATTENUATION FACTOR	AMPLIFIER GAIN	TOTAL GAIN FACTOR
20V	÷ 1000	4	.004
10V	÷ 1000	8	.008
5V	÷ 100	1.6	.016
2V	÷ 100	4	.04
1V	÷ 100	8	.08
500mV	÷ 10	1.6	.16
200mV	÷ 10	4	.4
100mV	÷ 10	8	.8
50mV	÷ 1	1.6	1.6
20mV	÷ 1	4	4
10mV	÷ 1	8	8

To illustrate how the attenuator and switched-gain amplifier work together for the proper gain, assume the VOLTS/CM switch is in the 10mV position and a 10mV signal is applied to the input. Since the total gain factor is 8, the input signal is amplified by a factor of eight before it is coupled to follower Q107-1/Q108-1. An 80mV signal at the follower will cause a 1 cm deflection in the CRT screen. Now assume the VOLTS/CM switch is in the 500mV position and a 500mV signal is applied to the input. The total gain factor is now .16. Multiplying the input signal by the total gain factor results in an 80mV signal to the follower (500mV x .16 = 80mV), again causing a 1 cm deflection on the CRT screen.

Differential emitter follower Q107-1/108-1 serves as a buffer between the switched-gain amplifier and second amplifier. It also provides vertical trace positioning. Y1 Position control R138-1 controls trace position by shifting the emitter current between the two emitter circuits. From the follower, the signal is coupled to the trigger amplifier and second amplifier. The trigger amplifier will be described after the "Vertical Deflection" section.

The second amplifier is a differential amplifier with a gain of approximately 10. Its output is direct-coupled to the diode bridge. CAL control R164-1 adjusts the gain of this amplifier and the overall calibration of the vertical circuit.

DIODE SWITCH

Both preamplifier circuits (channels Y1 and Y2) share the vertical deflection amplifier. This is accomplished with two high-speed diode switch networks (D107-1 thru D110-1 and D107-2 thru D110-2) that are actuated by the display control circuit. When one diode switch is turned on, the other is turned off so that only one signal can be coupled to the vertical deflection amplifier. Two-channel operation is accomplished by turning each diode switch network on and off at a rapid rate or on alternate display sweeps. Control of the diode switch will be described in a later section.

VERTICAL DEFLECTION

From the diode switch, the input signal is direct-coupled to the vertical deflection amplifier. This amplifier (comprising transistors Q111, Q112, Q113, and Q114) is wired in a differential cascade configuration, with a gain of approximately 20. Capacitor C126 across the emitters of Q111 and Q112 provides high-frequency square wave compensation. Ferrite beads FB101 and FB102 in common-base amplifier Q113/Q114 prevent oscillations in the amplifier. Circuit loading is supplied by resistors R174 and R176, while inductors L101 and L102 serve as peaking coils. The output of this amplifier is coupled to the vertical deflection plates of the CRT for beam control. Vertical beam deflection requires between 12 and 15 volts/cm, depending on individual CRT charactistics. The vertical CAL control, R164-1, in the vertical input circuit adjusts overall vertical gain to match the CRT deflection characteristics.

TRIGGER AMPLIFIER

A differential amplifier and follower comprise the trigger amplifier circuit. Its output is used to supply a trigger signal to the horizontal time base, trigger, and sweep circuits. In addition, the Channel Y1 trigger signal can be switched to the horizontal deflection circuit for X-Y operation.

A portion of the input signal is coupled from follower Q107-1/Q108-1 to the input of the differential amplifier in the trigger amplifier circuit. Emitter follower Q117-1 couples the trigger signal from the inverting leg (Q115-1) of the differential amplifier (Q115-1/Q116-1) to the horizontal time base, trigger, and sweep circuits. Transistor Q118-1 is a temperature-compensated constant current source for this circuit. The Zero control (R149-1) in the emitter leg adjusts the current so that the output of the follower will be zero with no signal to the trigger amplifier. Thus, the circuit performs as a differential to single-ended converter.

TRIGGER, SWEEP, AND CONTROL

On command from a trigger pulse, the horizontal time base circuits generate a linear ramp signal (sweep) to drive the CRT horizontal deflection plates and move the dot across the screen at a constant rate. In the automatic triggering mode, if no trigger is present, the time base circuits free-run and generate an auto-baseline. An oscillator provides the vertical signal chop rate when two traces are displayed in the chop mode (TIME/CM sweep rate is 5 mS and slower). Figure 11 shows a typical, two trace, chopped display that has been exaggerated for clarity.

When a trigger pulse of sufficient amplitude is present, the trigger comparator outputs change logic and a trigger signal passes through the slope selector gate. The signal from the gate turns on the sweep control and allows the time capacitor to be charged through the "bootstrap" constant current source. The charging of the capacitor produces a linear ramp signal that is coupled through the voltage follower to the horizontal deflection circuits.

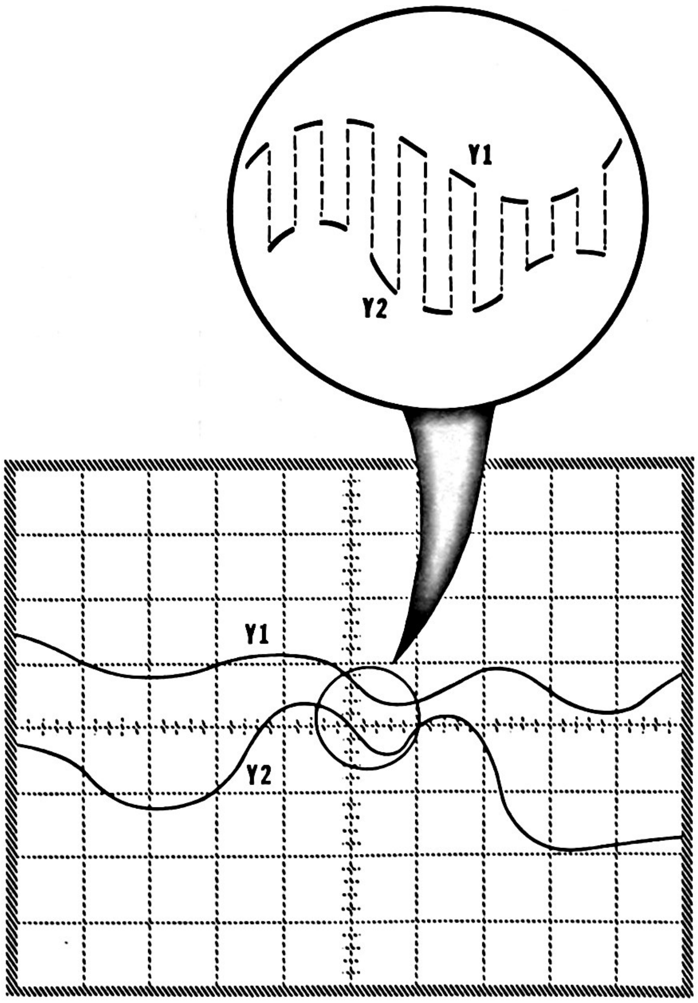


Figure 11

The ramp signal is also coupled to the sweep end circuit. When the ramp reaches a preset voltage level, set by the Sweep Length control, the sweep end circuit triggers the blanking flip-flop and sweep end monostable. The sweep end monostable insures that retrace will not occur until after the CRT has blanked.

TRIGGER

In the automatic triggering mode, the trigger circuit examines the trigger signal for a proper trigger point. If the signal is large enough, the sweep circuit is activated by the trigger. If the signal is insufficient or absent, the sweep circuits are allowed to free run.

Depending on the desired trigger mode, one of four sources can be selected by the Trig switch: External Trigger, Channel Y1 Trigger, Channel Y2 Trigger, or Line Sync. The Channels Y1 and Y2 Trigger signals are provided by the vertical preamplifier trigger circuits; while the Line Sync signal is tapped directly off of one side of the 6-volt transformer winding. The External Trigger signal is coupled through FET follower Q201/Q202 to the Trig switch. Transistors ZD201 and ZD202 function as reverse-biased zener diodes to limit the signal level to the input of Q201. FET Q202 is a constant current source.

The trigger signal is coupled from the Trig switch, through the Trig Mode switch, to the pin 5 input of differential trigger comparator IC201. The trigger comparator compares the trigger voltage at pin 5 to the reference voltage at pin 4. If the trigger voltage is greater than the reference voltage, the noninverting output (pin 11) is at a logic high* and the inverting output (pin 10) is low. When the trigger voltage goes lower than the reference voltage, the comparator outputs will switch levels; the noninverting output will go low and the inverting output will go high. Thus, each trigger pulse, of sufficient amplitude, is converted to a logic pulse. In both "auto" and "normal" operation, Level control R213 adjusts the reference voltage level (Diodes D205 and D206 set the range of the control to approximately ±0.7 volts). The complementary trigger comparator output is coupled to ± slope selector gate IC202. (Feedback resistors R209 and R211 supply circuit hysteresis so that the comparator will not switch on Noise pulses.)

*A logic high (1) is greater than 2.4 volts DC, but less than 5.5 volts DC. A logic low (0) is less than or equal to 0.8 volts DC.

Trigger slope selection is determined by the TRIG switch and the slope selector gate, IC202, as shown in Figure12.The slope selector gate functions as a two input multiplexer and couples the pin 11 or pin 10 output of IC201 to the sweep circuits, as determined by the TRIG switch. When the control line is at a high level (+ slope), pin 4 of gate B is at a logic high. This enables gate B so the pin 10 output of IC201 is inverted and coupled through to gate C. The logic high at pins 12 and 13 of gate D is inverted and coupled to pin 2 of gate A. The logic low at pin 2 disables gate A and forces its output high. A high on pin 10 of gate C enables gate C, to invert and couple the signal from gate B to the sweep control circuit and auto-baseline circuit. When the control line from the TRIG switch is at a low level, the slope selector gate couples the signal from pin 11 of IC201 to the sweep control circuit and auto-baseline circuit.

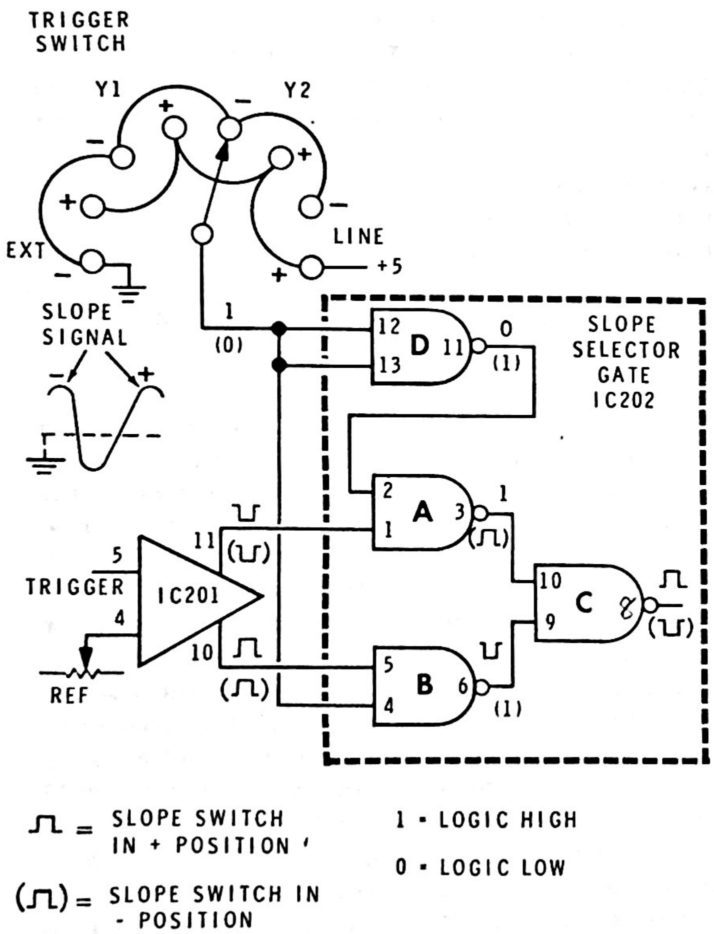


Figure 12

SWEEP

The negative edge of the trigger pulse activates IC203B and turns transistor Q203 off. This lets the timing capacitor charge through the bootstrap current source, and generates a linear voltage ramp. The ramp (sweep signal) is coupled to the horizontal deflection circuit, and the remaining sweep circuits. When the ramp reaches a predetermined level, the CRT is blanked, IC203B is reset, and Q203 is turned on to provide a discharge path for the timing capacitor (ramp returns to zero level).

Refer to Figure 13 for the following discussion.

When transistor Q203 turns off, the timing capacitor begins to charge. After approximately 10 nS, the CRT unblanks and the trace becomes visible. This short delay hides any switching transients. At a preset ramp level, the CRT is again blanked before the trace is stopped (to give the CRT time to fully blank). After the short delay, transistor Q203 is turned on and the timing capacitor is discharged.

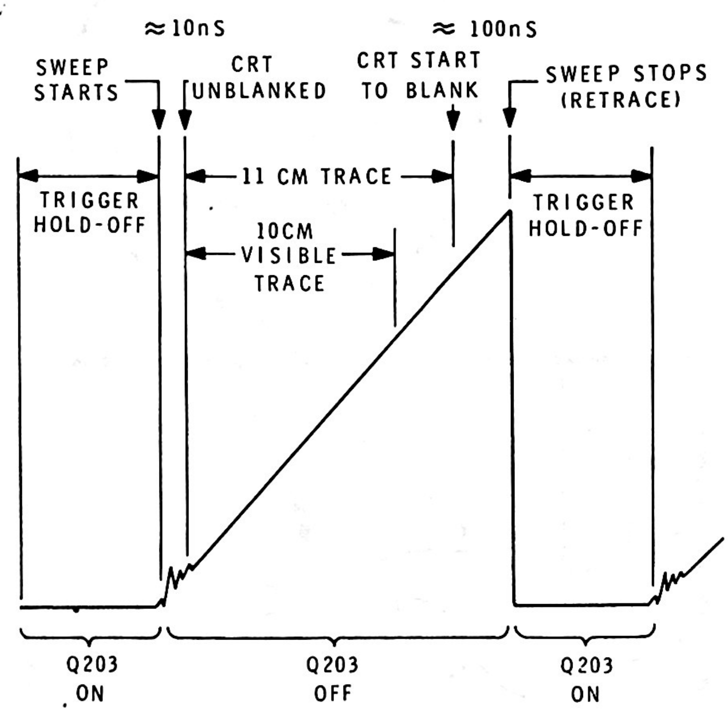


Figure 13

Initially, sweep control IC203B is in a reset condition (Q is low and $\overline{Q}$ is high) and transistor Q203 is turned on. A trigger pulse from slope selector gate IC202 will toggle IC203B and switch Q high and $\overline{Q}$ low. The low from $\overline{Q}$ turns transistor Q203 off and toggles blanking control IC203A. As Q203 turns off, the timing capacitor begins to charge through the bootstrap current source. At the same time, IC203A switches the CRT blanking circuit and unblanks the CRT.

The "bootstrap" current source is part of the sweep generator. FET Q204 and Q205, and transistor Q206 form a voltage follower with a gain of approximately 1. It has a very high input impedance to prevent circuit loading, which could cause a non-linear voltage ramp (sweep). The junction of resistors R252 and R253 are held to a level 10 volts above the output of the follower by 5-volt zener diodes ZD210 and ZD211. Since the follower input voltage equals the output voltage, the voltage across the selected timing resistor will always be constant. This will produce a constant current to charge the selected timing capacitor. When variable control R253 is turned from its Cal position, the voltage differential is lowered. Thus the charging current will be reduced and as a result, reduce the sweep speed. The Variable control is used to provide continuous sweep speeds between calibrated ranges. Ramp Zero control R248 adjusts the follower for proper voltage offset.

The output of the sweep generator is coupled through resistor divider R259, R261 to the horizontal deflection amplifier. It is also coupled through Sweep Length control R255 to sweep and Schmitt gate IC207A. Sweep Length control R255 is adjusted so that the output of the Schmitt trigger-type gate will go low when the ramp voltage exceeds approximately 1.6 volts. (This represents a horizontal sweep of approximately 11 centimeters.) The low from IC207A resets (clears) blanking control IC203A, which blanks the CRT. Zener diode ZD209 protects the Schmitt trigger from misalignment or malfunction of the sweep generator, IC207B. The function of IC207B will be described later.

The low from sweep end gate IC207A is also coupled to the sweep end monostable IC204C and D. This converts the low level signal to a short duration negative pulse (approximately 100nS, which gives the CRT time to fully blank) and couples it to hold-off monostable IC206. The hold-off monostable toggles ($\overline{Q}$ goes low) and remains in this condition until it "times out." The hold-off time is determined by the TIME/CM switch, and is of sufficient duration to insure complete retrace. With pin 1 of IC209A high (from IC207B), the low from $\overline{Q}$ of IC206 will force pin 3 of IC209A low and reset sweep control IC203B. This forces the $\overline{Q}$ output high and turns on Q203, which quickly discharges the sweep timing capacitor (retrace). The low from pin 3 of IC209A does not affect gate IC204A, because pin 2 of IC204A is already low (auto-baseline monostable IC205 toggled by trigger signal). The low from hold-off monostable IC206 "locks-up" sweep control IC203B, so that it cannot toggle on a trigger signal until after hold-off. After IC206 "times out", IC203B can toggle on the next trigger signal and start a new sweep cycle.

If for any reason the sweep control circuitry should "hang-up", such as at initial turn-on, the ramp voltage would continue to increase. A voltage level would be reached where anti-lockup control IC207B would activate and (through IC209A) reset (clear) IC203B, and discharge the sweep timing capacitor, to initiate a new sweep cycle.

Normally, reoccurring Trigger pulses hold monostable IC205 on. The low at the $\overline{Q}$ output is coupled through IC209B and holds the output of IC204A high for normal sweeps to take place. However, with no input trigger pulses, IC205 times out and its $\overline{Q}$ output goes high. This (through IC209B) forces the output of IC204A low, which allows IC203B to "free run" and produce sweeps for a base line. In "normal" mode operation, the automatic base line will never appear as this feature is overridden by switch SW204.

CONTROL

For single-channel operation, the diode switch is latched by the diode switch control circuit to couple the selected input to the vertical deflection circuit. When an input channel is turned on (switch on Position control), a logic high is placed on the J or K input (depending on which channel is turned on) of display control IC211. The first low-to-high level transition at the $\overline{Q}$ output of IC203B (sweep stop) is coupled to pin 5 of IC204B. With a high on pin 4 of IC204B, the signal on pin 5 is inverted and coupled through IC210C (pin 10 high) to the clock input (pin 12) of IC211. The high-to-low level transition toggles IC211 and couples the information at the J input to the Q output. Thereafter, each "clock" pulse will have no effect while the J input level does not change. The Q output (high for Y1 and low for Y2) is coupled to the input of the diode switch control.

A logic high to the diode switch control will turn transistor Q120 on and reverse bias diodes D109-1 and D110-1. Diodes D107-1 and D108-1 are then forward biased and the signal for Channel Y1 is coupled to the vertical deflection amplifier. With transistor Q120 turned on, Q121 is turned off. Diodes D109-2 and D110-2 are forward biased, and D107-2 and D108-2 are reverse biased, which blocks the Channel Y2 signal. The reverse occurs when a logic low is coupled to the diode switch control circuit.

Dual-channel operation is enabled when both input channels are turned on (switch on each Position control). The TIME/CM switch selects either the chop mode (.2 SEC to 5mS range) or the alternate channel mode (2mS to .2μS range). When both channels Y1 and Y2 are turned on, logic highs are coupled to the J and K inputs of display control IC211. Gate IC210A is also enabled to put pin 4 of IC210B high.

In the alternate channel mode, pin 12 of IC210D is grounded (low) by the TIME/CM switch — which disables IC210D and the chopper oscillator (IC208C, IC208B). At the beginning of a sweep, the high-to-low level transistion at $\overline{Q}$ of IC203B is inverted by IC204B (pin 4 is high) and coupled through IC210C (pin 10 is high) to pin 12 of IC211. This "sets" the display control. At the end of the sweep, the low-to-high level transition from the $\overline{Q}$ output of IC203B toggles IC211 and the Q output changes "state" (low to high or high to low transistion). Output Q is coupled to the diode switch control circuit. A logic high will couple the Channel YI signal to the vertical deflection circuit. A logic low will couple Channel Y2. Each successive sweep cycle will toggle IC211 and alternate the channel being coupled through the diode switch to the vertical deflection circuits.

For chop mode operation, an oscillator provides a switching signal to the display control. This forces the diode switch to alternately couple Channels Y1 and Y2 to the vertical deflection circuit many times during each sweep. Because the switching rate is fast (approximately 200 kHz) and the sweep rate is slow, the chopped effect of the display is not visible. Pin 12 of IC210D is high, which enables IC210D. When a new sweep cycle begins, the Q output of IC203B goes high. This high is coupled through IC210D to pin 9 of the chopper oscillator (IC208C and IC208B) and turns the oscillator on. The low from $\overline{Q}$ of IC203B is inverted by IC204B to enable IC210C. Therefore, each low-high-low pulse from the chopper oscillator will be coupled through resistor R223 and IC210C to the clock input of IC211. Each clock pulse is also coupled through IC210B to the chop blanking amplifier. The short time delay caused by the RC network R223 and C215 insures that the CRT will be blanked when the diode switch switches from one input channel to the other. This serves two functions: First, blanking the CRT will remove any trace lines that may appear when the vertical circuits switch between input channels. Second, the short delay between blanking and switching will hide any possible switching noise that may be generated. At the end of the sweep cycle, the chopper oscillator is turned off by the Q output of IC203B. This removes the possibility of a false trigger after hold-off. A new sweep cycle will start the chopper oscillator again.

Each chop pulse from IC210B is coupled to the chop blanking amplifier through capacitor C417 on the high voltage circuit board. Capacitor C417 acts as a differentiator to convert the incoming square wave to dual-polarity spikes (see Figure 14). Resistor R428 holds transistor Q401 on until a negative spike turns Q401 off for a very short time, as determined by the value of C417. The positive portion of the spike has no effect on the circuit. When Q401 turns off, the collector voltage rises sharply to +68 volts. This short pulse is coupled through capacitor C418 to effectively pull the CRT cathode voltage up to —1632 volts, which will momentarily blank the CRT. Normal CRT blanking (for retrace) will be described with the high voltage power supply.

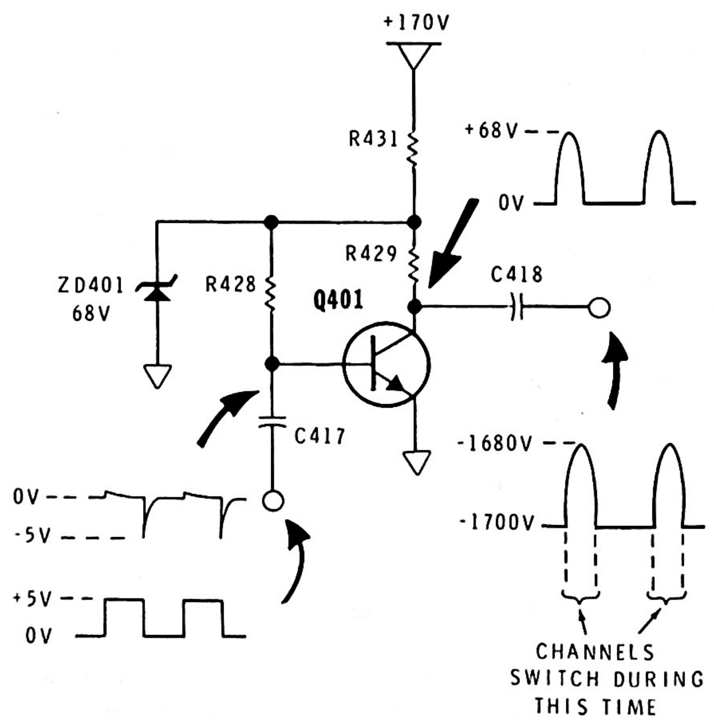


Figure 14

HORIZONTAL

The horizontal signal is coupled from the sweep generator to the base of Q210 in the first horizontal deflection differential amplifier (Q210/Q211). A reference voltage from the horizontal position control provides a coarse (R263A) and fine (R263B) offset adjustment at the differential amplifier (base of Q211). Amplifier gain is approximately 10. Control R268 adjusts the gain of this amplifier, and hence the overall gain of the horizontal deflection circuit. This is to compensate for the individual deflection characteristics of the CRT. Transistor Q216 is the constant current source for this amplifier section.

Final amplification occurs in the second deflection amplifier. It is a cascade differential amplifier with a gain of approximately 25. The output is coupled to the horizontal deflection plates of the CRT for beam control. Horizontal beam deflection requires between 19 and 25 volts/cm, depending on individual CRT characteristics. Control R278 is used to adjust the emitter resistance of Q212/Q213 so that when the X5 switch (SW204) is closed, the gain of the second amplifier is multiplied by exactly 5.

When X-Y operation is desired, the trigger signal from the Channel Y1 trigger amplifier is coupled to the base of Q210 through the TIME/CM switch. The TIME/CM switch also grounds the clear input to the display control (IC211). This forces the Q output low to insure that the diode switch couples the Channel Y2 signal to the vertical deflection amplifier. The low from the TIME/CM switch also presets the blanking control to insure that the CRT remains continuously unblanked. X-Y CAL control R258 is used to calibrate overall horizontal deflection gain for the X-Y mode; while capacitor C233 reduces high frequency phase-shift.

External X operation allows you to look at two signals in relation to a third signal, sort of a two channel X-Y. With the TIME/CM switch in the Ext X position, a low is coupled to IC203A (through IC209D) to preset the blanking control and unblank the CRT. The chop oscillator is unlatched and allowed to run continuously (sweep circuit disabled). The external sweep signal is coupled to the horizontal deflection amplifier through the external horizontal input buffer. The buffer functions as a dual-inverted emitter follower. This provides a high input impedance while maintaining a gain of approximately 1 with low offset voltage. (The emitter-base drops of Q207 and Q208 cancel.) Transistors ZD212 and ZD213 function as reverse-biased zener diodes to limit the signal level to the base of Q207.

POWER SUPPLIES

+170 AND +150 VOLTS

Full-wave rectifier diodes D301, D302, D303, and D304 produce the +170-volt supply used in the horizontal deflection amplifier, the chop blanking amplifier, and the Astigmatism control. A second filter divides the 170-volt source down to +150 volts for the vertical deflection amplifier.

±15 VOLTS

Diodes D305, D306, and D307, D308 comprise two full-wave rectifiers that produce positive and negative 21 volts DC from the power transformer. These are filtered and then coupled through pass transistors Q301 and Q302. Transistor base voltage is set by the dual-polarity tracking regulator IC301. Resistors R306 and R307 set the maximum current that the regulator will supply. This limiting, in turn, limits the supply current for short circuit protection.

Voltage adjust control R309 calibrates the –15 volt line and, through the regulator, the +15 volt line. Capacitors C307 and C308 reduce load transients.

±5 VOLTS

Full-wave rectifier diodes D309, D310, D311, and D312 produce a positive and negative 8-volts DC from the power transformer. Capacitors C309 and C311 filter the raw DC, while transistors Q303 and Q305 serve as pass elements. Their outputs are limited to 5 volts by zener diodes ZD313 and ZD314, which are connected to the base of each transistor. In the positive 5-volt supply, resistor R315 sets the base-emitter current of Q304 to shut down the supply above approximtely 400mA. Resistor R313 and transistor Q306 limit the negative 5-volt supply to approximately 100mA. Capacitors C313 and C312 reduce load transients.

The line sync trigger signal is coupled from the 8-volt transformer secondary winding through resistor R206 to the Trig switch. The pilot lamp and resistor R7 are also connected across the 8-volt transformer secondary winding.

HIGH VOLTAGE

Diodes D404 and D405, and capacitors C408, C409, C410, and C411 comprise a voltage doubler that produces approximately –2000-volts DC at nominal line voltage. The positive output of the doubler is connected to the collector of pass transistor Q404/Q405/Q406. (The three transistors are wired in series to form a single high voltage pass transistor.) At nominal line voltage, the voltage at the collector of Q404 is approximately +300 volts. The +300 volts and –2000 volts add together to produce the –1700 volts supplied to the cathode of the CRT. Control R409 is adjusted for optimum voltage regulation, while resistor R427 provides cathode current limiting. Divider resistor string R423, R424, R3, R425, and R426 supply a reduced voltage for the Focus control (R3). A current summing junction at the end of the divider string adds the high voltage current (approximately 340μA) to a reference current supplied by the +15 volt supply through control R419 and couples it to operational amplifier IC401. Control R419 is adjusted so that the reference current is equal to, but opposite the high voltage (HV) current, when the high voltage is at the correct level (–1700 volts).

If the high voltage falls below –1700 volts, the current difference at IC401 will cause IC401 to increase the base drive to Q404/Q405/Q406 and thus decrease the collector voltage until the high voltage again equals –1700 volts. This will again make the HV current equal to the reference current. The reverse will occur when the high voltage exceeds –1700 volts.

The frequency response of this circuit is high enough so that it also operates as a filter to remove 120 Hertz ripple from the high voltage. Upper frequency response is limited by capacitor C414 to suppress any possible high frequency oscillation in IC401. Diode D406 protects the pass transistor from a reverse output from IC401. Resistors R411, R412, and R413 insure equal voltage distribution between Q404, Q405, and Q406.

CRT BLANKING

The CRT blanking circuit is used to control the electron beam in the CRT. This includes blanking the CRT during "retrace" and "hold-off", and trace intensity. To fully understand this circuit, you must keep three ideas in mind:

1. The CRT is blanked when the control grid is 68 volts more negative than the cathode.

2. As the 68-volt difference between the grid and cathode is reduced the CRT is unblanked, and the beam intensity is increased.

3. Since the cathode of the CRT is at –1700 volts, the grid must vary between –1700 volts and –1768 volts. Therefore, the blanking circuit must be completely isolated from the other oscilloscope circuits. CAUTION: When measuring voltages in the blanking circuit keep in mind that "circuit common" is 1700 volts below oscilloscope ground.

Diodes D402 and ZD403, capacitors C401 and C402, and resistor R401 comprise a –68 volt regulated power supply. The positive end of the supply is tied to the –1700 volt supply. The –68 volt supply powers a simple flip-flop (Q402, Q403). This flip-flop is toggled through high voltage capacitors (C403, C406) by blanking control IC203A. Because of the capacitor coupling normal ground-referenced logic levels can be used for control.

Assume the flip-flop is toggled so that Q402 is off, and Q403 is on (unblanked CRT condition). The cathode is near –1700 volts and the other end of control R2 is at –1768 volts [–68 (+) –1700]. As the Intensity control (R2) is turned clockwise, the beam intensity will increase (grid voltage approaches cathode voltage).

A blanking signal from IC203A (low-to-high logic transition at C406 and high-to-low logic transition at C403) will toggle the flip-flop and turn Q402 on and Q403 off. Now both ends of control R2 are at –1768 volts, and the CRT will blank. The reverse will occur when an unblanked signal from IC203A is sensed. Resistors R404 and R405 hold the flip-flop in a stable state after each toggle; while capacitors C404 and C405 speed up the switching cycle. The RC network, R407, R408, and C407, shape the blanking signal. Resistor R408 also isolates the circuit.

CALIBRATOR

An oscillator circuit comprised of IC208A and IC208D, and their associated circuitry components generate an output of approximately 1000 Hz. This is coupled to the base of transistor switch Q209. When Q209 is turned off, a precise 1-volt level is connected to the output. Divider resistors R236, R237, and R238 set the output level. When Q209 is turned on, it grounds the output.

CALIBRATION

This section of the Manual is divided into two parts: "Initial Calibration" and "Touch-Up Adjustments." The "Initial Calibration" must always be performed after the Oscilloscope has been serviced or parts have been replaced.

The "Touch-Up Adjustments" must always be performed after the "Initial Calibration" and any time you doubt the accuracy of your calibrated Oscilloscope.

INITIAL CALIBRATION

The following equipment is needed to calibrate your Oscilloscope:

VTVM — Accurate to within 1% at 15 volts DC and able to measure 1700 VDC.

Heathkit Oscilloscope Calibrator — OR — A Square Wave Generator capable of producing 1 kHz to 1 MHz signals; with up to 5 volts output, rise time ≤5 nS, and overshoot ≤1%.

A 1000 Hz Square Wave Voltage Calibrator (1 to 100 volt output) is also recommended, but not necessary; accurate in amplitude to 1% at 1 volt; accurate in frequency to 1%.

Controls and adjustments associated with Channel Y1 are identified as Y1, CH1, or a "-1" following the circuit component number, such as R119-1. Channel Y2 controls and adjustments are identified as Y2, CH2, or a "-2" following the circuit component number. Use a plastic alignment tool to make the adjustments.

If you do not obtain the proper results, turn the Oscilloscope off, refer to the "In Case of Difficulty" section of the Manual, and correct any difficulties before you proceed.

Turn off the Oscilloscope and disconnect the line cord plug from the AC power source.

Loosen the knurled knob on each side of the chassis and remove the top and bottom covers. Be careful not to touch any of the circuitry when you move the Oscilloscope around for various adjustments. Dangerous voltages are present. See Figure 23 (in the "Illustration Booklet").

VOLTAGE ADJUSTMENTS

Refer to Parts A and B of Figure 15 (in the "Illustration Booklet") for the following steps.

1. Adjust your voltmeter to measure −15 volts DC.

2. Connect the common voltmeter lead to the Oscilloscope chassis.

3. Measure the voltage at test point 4 (TP4, on the low voltage circuit board). Adjust control R309 (on the low voltage circuit board) for a −15 volt meter indication. (Interchange your meter leads if necessary.)

4. Adjust your voltmeter to measure −2000 volts DC.

5. Measure the voltage at lug 1 of control R2. Adjust the HI VOLT ADJ control (R419, on the high voltage circuit board) for −1700 volts DC (±10 volts).

BEAM ADJUSTMENTS

Refer to Figure 1 (in the "Illustration Booklet") for the circuit component number of any front panel control or switch.

1. Set the indicated front panel controls as follows:

Y1:

INPUT switch (AC-GND-DC)	GND
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
POSITION	Fully counterclockwise (OFF)

Y2:

INPUT switch (AC-GND-DC)	GND
VOLTS/CM	50 mV
VOLTS VARIABLE	Fully clockwise (CAL)
POSITION	Center trace on screen

OTHER:

VARIABLE - X5	Fully clockwise (CAL) and pushed in.
TRIG	Y1, +
LEVEL	Center of rotation and pushed in.
TRIGGER MODE	AC
TIME/CM	EXT
HORIZ POS	Center spot on screen.

2. Turn the INTENSITY control counterclockwise to decrease the brightness of the spot. Readjust this control as necessary to keep the spot small when you make the following focus and astigmatism adjustments.

3. Alternately adjust the FOCUS control and the ASTIGMATISM control R427 (a screwdriver adjustment through the rear panel) to obtain the smallest possible round spot on the CRT screen.

4. Set the indicated front panel controls as follows:

TIME/CM	.1 mS
Y2 POSITION	Fully counterclockwise (OFF)
Y1 POSITION	Center trace on screen
HORIZ POSITION	Position trace on screen

VERTICAL AMPLIFIER BALANCE

NOTE: During the following steps, you may experience the rare situation that the vertical amplifier of one channel will not balance properly. If this happens, interchange transistors Q101 and Q102 of the channel that does not balance. The transistor leads are not soldered to the socket pins.

Channel Y1: Perform the following numbered steps 1-11. Adjust only the controls associated with Channel Y1.

1. Adjust the POSITION control to place the trace on the horizontal centerline.

2. Turn the VARIABLE control fully counterclockwise. The trace may move off the screen.

3. Adjust the POSITION control to return the trace to the center horizontal graticule line.

4. Turn the VARIABLE fully clockwise (CAL).

5. Slowly adjust the DC BAL control (a screwdriver adjustment through the front panel) to return the trace to the center horizontal graticule line.

6. Repeat steps 2 through 5 until the trace does not move when you turn the VARIABLE control. Leave the VARIABLE control in the fully clockwise position (CAL).

7. Turn the VOLTS/CM switch to the 10mV position.

8. Adjust the BAL control [R124, on the vertical circuit board (see Figure 16)]to return the trace to the center horizontal graticule line.

9. Turn the VOLTS/CM switch back and forth between the 10mV position and the 50mV position and adjust the BAL control so the trace does not move when the switch is turned from one position to the other.

10. Repeat steps 2 through 5.

11. Turn the Y1 POSITION control fully counterclockwise (OFF). Then turn the Y2 POSITION control clockwise and center the trace on the screen.

Channel Y2: Perform the previous numbered steps 1-10. Adjust only the controls associated with Channel Y2.

TRIGGER

1. Set the Y1 and Y2 INPUT switches to GND.

2. Adjust the Y1 and Y2 POSITION controls to place both traces on the horizontal centerline.

3. Adjust your voltmeter to measure –3.0 volts DC.

4. Connect the common voltmeter lead to the Oscilloscope chassis.

5. Measure the voltage at TP14 (test point 14) on the vertical circuit board. (See Figure 16 in the "Illustration Booklet.") Adjust the Y1 ZERO control (R149-1, on the vertical circuit board) for zero volts.

6. Measure the voltage at TP15 on the vertical circuit board. Adjust the Y2 ZERO control (R149-2, on the vertical circuit board) for zero volts.

7. Disconnect the voltmeter.

VERTICAL AMPLIFIER

1. Set the indicated front panel controls as follows:

TIME/CM	1 mS
Y1:	
VOLTS/CM	200 mV
POSITION	Center trace on screen
INPUT switch	GND
Y2:	
VOLTS/CM	200 mV
POSITION	Fully counterclockwise (OFF)
INPUT switch	GND

2. Channel Y1: Perform the following lettered steps (A-G). Adjust only the controls marked Y1 or associated with Channel Y1.

   A. Adjust the POSITION control to place the trace on the horizontal centerline.

   B. Make sure the VARIABLE control is fully clockwise (CAL) position.

   C. Set the INPUT switch to AC.

   D. Connect the test cable inner lead to the 1V P-P connector on the front panel. NOTE: A Square Wave Voltage Calibrator may be used instead of the 1V P-P output from the Oscilloscope.

   E. Adjust the CAL control (R164, on the vertical circuit board) and the POSITION control for a waveform exactly 5 cm high between the flattest portions.

   F. Disconnect the test leads from the 1V P-P connector.

   G. Turn the POSITION control fully counterclockwise (OFF).

3. Channel Y2: Turn the TRIG switch to the Y2, + position. Then perform the previous lettered steps (A-G) again for Channel Y2. Adjust only the controls marked Y2 or associated with Channel Y2.

SWEEP

1. Set the indicated front panel controls as follows:

Y1 INPUT switch	AC
TRIG	Y1, +
TIME/CM	1 mS
VARIABLE	CAL

2. Connect a 1000 Hz square wave signal to the Y1 INPUT connector. Adjust the signal amplitude for a 2-4 cm vertical display.

3. Adjust the SWEEP LENGTH control (R255, on the horizontal circuit board) so the trace is 10 cm long.

4. Refer to Figure 17 in the "Illustration Booklet" and carefully adjust the X CAL control (R268, on the horizontal circuit board) and the HORIZ POS control for exactly 10 cycles in 10 centimeters (1 cycle per centimeter) as shown in Figure 18. Use the leading edge of the second and tenth cycle for this adjustment.

5. Readjust the SWEEP LENGTH control (R255, on the horizontal circuit board) so the trace is 10 cm long.

6. Turn the HORIZ POS control counterclockwise to move the right-hand end of the trace 1 cm to the left.

7. Adjust the SWEEP LENGTH control (R255, on the horizontal circuit board) to move the right-hand end of the trace back to the right 1 cm.

8. Readjust the HORIZ POS control so the left-hand edge of the trace starts at the left-hand graticule line.

9. Pull out the VARIABLE — X5 switch.

10. Adjust the X5 CAL control (R278, on the horizontal circuit board) and the HORIZ POS control for exactly 2 cycles in 10 centimeters as shown in Figure 19. When you make this adjustment, place the leading edge of the first cycle on the left-hand graticule line and the leading edge of the second cycle on the center graticule line.

11. Push in on the VARIABLE — X5 switch.

12. Place the Y1 INPUT switch in the GND position.

13. Adjust the RAMP ZERO control (R248, on the horizontal circuit board) until the bright spot on the left end of the trace disappears. (This is not a critical adjustment.)

14. Place the INPUT switch to AC.

15. Refer to Figure 17 in the "Illustration Booklet," and carefully readjust the X CAL control (R268, on the horizontal circuit board) and the HORIZ POS control for exactly 10 cycles in 10 centimeters (1 cycle per centimeter) as shown in Figure 18. Use the leading edge of the second and tenth cycle for this adjustment.

16. Turn the TIME/CM switch to 1 μS.

17. Connect a 1 MHz square wave signal to the Y1 INPUT connector.

18. Use a plastic alignment tool and adjust trimmer capacitor C229 (located on the TIME/CM switch) for 1 cycle per centimeter.

19. Disconnect the square wave signal.

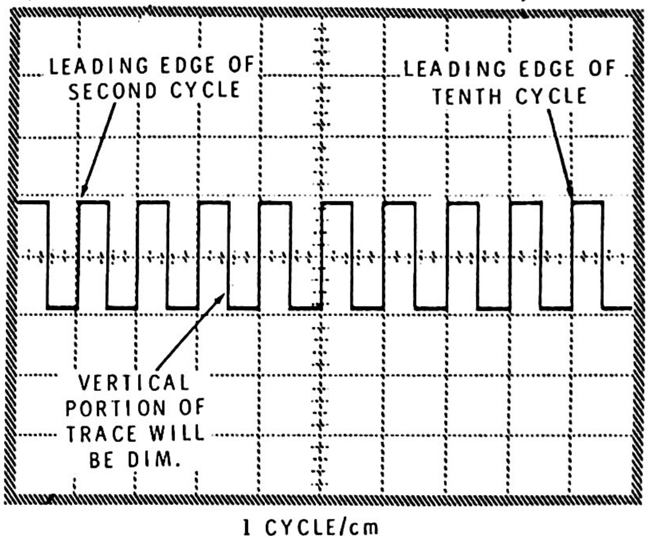


Figure 18

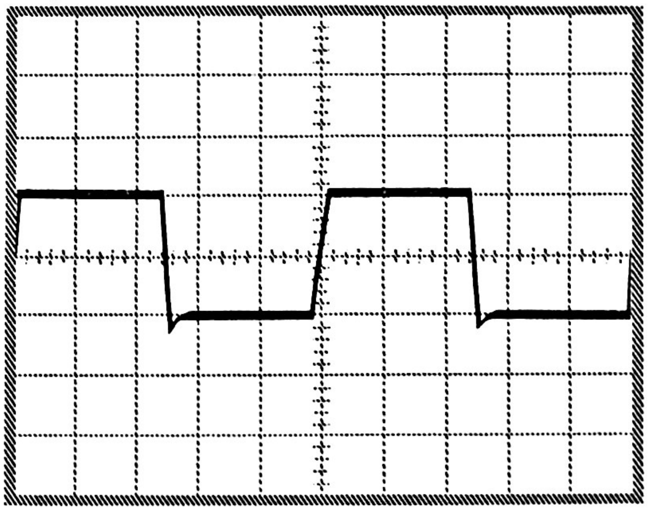


Figure 19

X-Y

1. Turn the Y1 VOLTS/CM switch to the 200mV position.

2. Turn the TIME/CM switch to the X-Y position.

3. Turn the TRIG switch to Y2, +.

4. Adjust the Y1 and Y2 POSITION controls to center the spot on the graticule. Adjust the HORIZ POS control so the Y1 POSITION control will move the spot off the screen in both directions.

5. Set the Y1 INPUT switch to AC.

6. Connect the Y1 test cable inner lead to the 1V P-P connector on the front panel. NOTE: A square wave voltage calibrator may be used instead of the oscilloscope 1V P-P output.

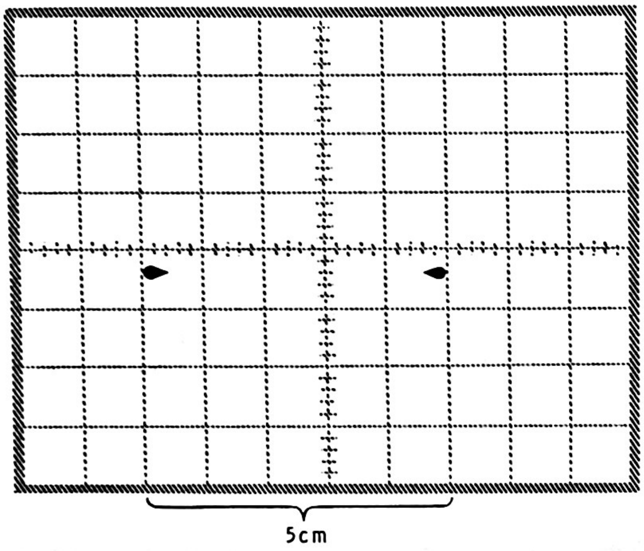


Figure 20

7. Adjust the X-Y CAL control (R258, on the horizontal circuit board) to place the two dots exactly 5 cm apart as shown in Figure 20.

8. Disconnect the Y1 test cable from the 1V P-P connector.

CHOPPED BLANKING

1. Turn the TIME/CM switch fully counterclockwise to the EXT position.

2. Use the Y1, Y2, and HORIZ POSITION controls and position the dots as shown in Figure 20A or 20B.

3. If the dots look like those in Figure 20A, proceed to "Attenuator Compensation."

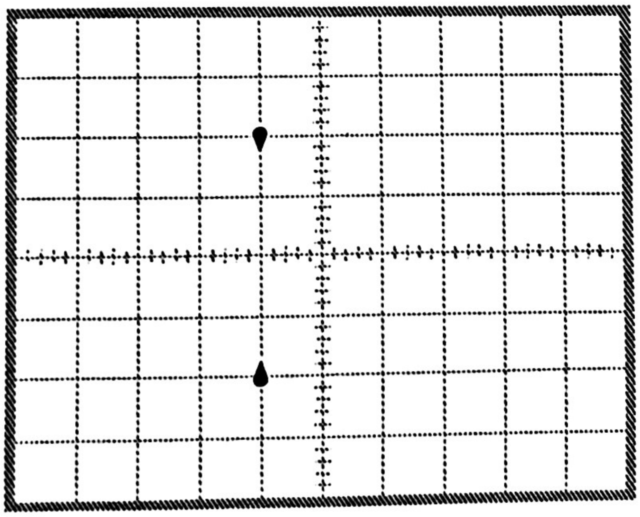


Figure 20A

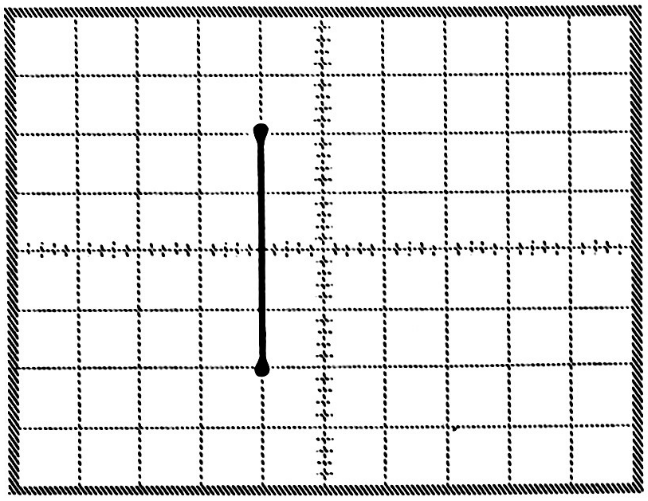


Figure 20B

If the dots look like these in Figure 20B (connected together), turn CHOP BLANK ADJ control R428 until the dots look like those in Figure 20A. Then proceed to "Attenuator Compensation."

ATTENUATOR COMPENSATION

The purpose of the following adjustments is to obtain the proper amount of high frequency compensation for each position of the VOLTS/CM switch. Parts A, B, and C of Figure 21 show the conditions of too much compensation, too little compensation, and the correct amount of compensation respectively. Use a plastic alignment tool to make the following adjustments.

1. Set the indicated front panel controls as follows:

TIME/CM	.2 mS
TRIG	Y1, +
Y1:	
INPUT switch	AC
VARIABLE	Fully clockwise (CAL)
VOLTS/CM	100 mV
POSITION	Center trace on screen

Y2:

INPUT switch	AC
VARIABLE	Fully clockwise (CAL)
VOLTS/CM	100mV
POSITION	Fully counterclockwise (OFF)
HORIZ POS	Center the trace on the screen.

2. Channel Y1: Refer to Figures 16 and 21, and perform the following lettered steps (A-I). Adjust only the controls that are marked Y1 or associated with Channel Y1.

   A. Adjust the POSITION control to place the trace on the horizontal centerline.

   B. Connect a 1000 Hz square wave signal to the INPUT connector. Adjust the signal amplitude of this signal for a trace 4 cm high. Readjust the amplitude of this signal as necessary in the following steps to maintain a suitable size trace (1-4 cm). (If your generator is a fixed amplitude type, you may use the 200 mV or 500 mV VOLTS CM position to obtain the proper display size.)

   C. Adjust trimmer capacitor C107 (÷ 10) to obtain the proper amount of compensation.

   D. Turn the VOLTS/CM switch to the 1V position (or 2V or 5V if necessary).

   E. Adjust trimmer capacitor C104 (÷ 100) to obtain the proper amount of compensation.

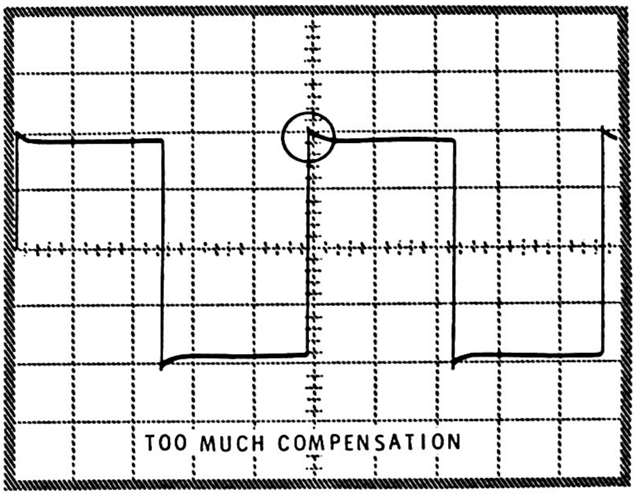
   F. Turn the VOLTS/CM switch to the 10V position (or 20V or 50V if necessary).

   G. Adjust trimmer capacitor C101 (÷ 1000) to obtain the proper amount of compensation.

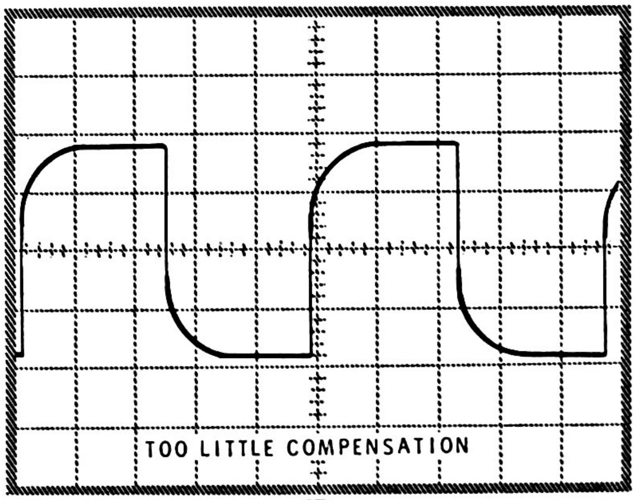
   H. Disconnect the square wave signal.

   I. Turn the POSITION control fully counterclockwise (OFF).

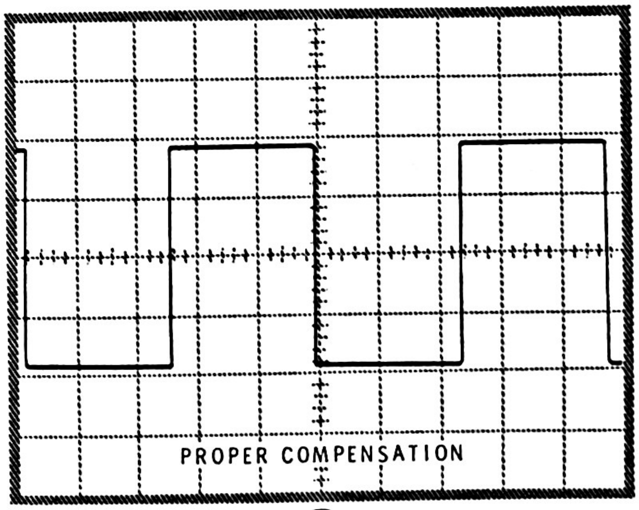
3. Channel Y2: Turn the TRIG switch to Y2,+. Then perform the previously lettered steps (A-I). Adjust only the controls that are marked Y2 or associated with Channel Y2.



A



B



C

Figure 21

SQUARE WAVE COMPENSATION

1. Connect a 1 MHz square wave signal to the Y1 INPUT connector.

2. Set the indicated front panel controls as follows:

TIME/CM	.2 uS
TRIG	Y1, +
Y1:	
INPUT switch	AC
VARIABLE	Fully clockwise (CAL)
VOLTS/CM	As necessary to produce a display similar to that shown in Figure 22.
POSITION	Center the trace on the screen.
Y2:	
INPUT switch	GND
VARIABLE	Fully clockwise (CAL)
VOLTS/CM	Same as Y1, above
POSITION	Fully counterclockwise (OFF)

NOTE: In the following step you will be instructed to adjust the displayed square wave for a certain "overshoot." This will produce the widest possible bandwidth for your Oscilloscope. You may adjust the square wave for a flat top. However, this will somewhat reduce your Oscilloscope bandwidth. Nevertheless, the bandwidth will still meet specifications.

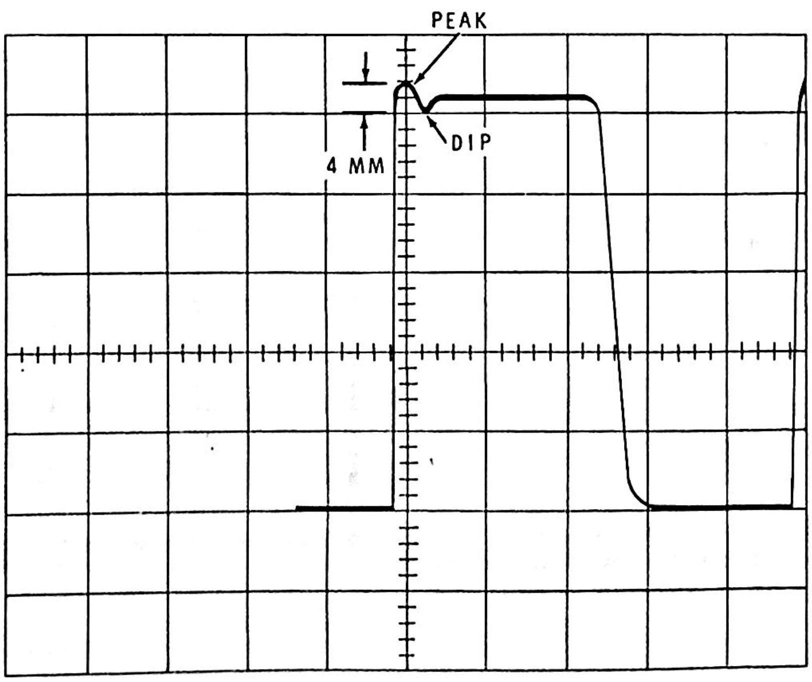
3. Position the trace as shown in Figure 22, with the VERT POS and HORIZ POS controls. The bottom of the dip should be on a horizontal graticule line. The "overshoot" peak height will vary with the setting of C118, the high frequency compensation trimmer (on the vertical circuit board). (Your dip may not look like the one shown.)

4. Adjust trimmer C118-1, with a nonmetallic screwdriver, so the top of the peak is no more than 4 mm from the bottom of the dip. NOTE: If you have trouble with this adjustment, check the two blue wires connected to the CRT socket for proper positioning.

5. Set the indicated front panel controls as follows:

Y1:	
INPUT switch	GND
POSITION	Fully counterclockwise (OFF)
Y2:	
INPUT switch	AC
POSITION	Center trace on screen
TRIG	Y2, +

Figure 22



6. Disconnect the 1 MHz square wave signal from the Y1 INPUT connector.

7. Connect a 1 MHz square wave signal to the Y2 INPUT connector.

8. Position the trace as shown in Figure 22. Then adjust trimmer C118-2 so the top of the peak is no more than 4 mm from the bottom of the dip.

9. Disconnect the 1 MHz square wave signal.

10. Turn the Y2 POSITION control fully counterclockwise (OFF).

This completes the "Calibration" of your Oscilloscope unless you have a low capacitance (X10) probe. Proceed to "Touch Up Adjustments" if you do not have such a probe. If you do, perform the following steps.

LOW CAPACITANCE PROBE

Perform the following steps only if you have a low capacitance (X10) probe that will compensate to approximately 40 pF (35-47 pF).

Probe Compensation and Amplifier Equalization

This adjustment procedure equalizes the input capacitance of both vertical amplifiers so a low capacitance probe can be used on either channel without the need to recompensate. If you have two probes, set one of them aside temporarily. Perform the following adjustments using one probe. Then connect the other probe and adjust only the probe trimmer for the proper amount of compensation.

1. Set the indicated front panel controls as follows:

Y1:

VOLTS/CM	10 mV
POSITION	Center the trace on the screen.
INPUT switch	AC
TIME/CM	.2 mS
TRIG	Y1, +

2. Connect the low capacitance probe to the Y1 INPUT connector.

3. Connect the probe end to a 1000 Hz square wave signal. Adjust the amplitude of this signal for a 4-5 cm display.

4. Adjust the probe trimmer for the proper amount of compensation as shown in Part C of Figure 21. Do not try to obtain the ultimate adjustment at this time.

NOTE: The trimmer capacitors called out in the following steps are on the vertical circuit board.

5. Adjust the Y1 input trimmer capacitor C111-1 (÷ 1) to obtain the maximum amount of overshoot on the leading edge of the waveform as shown in Part A of Figure 21. This adjustment sets the Y1 input trimmer capacitor at minimum capacitance.

6. Readjust the probe trimmer for the correct amount of compensation.

7. Disconnect the probe from the Y1 INPUT connector and connect it to the Y2 INPUT connector.

8. Set the indicated front panel controls as follows:

Y1:

POSITION	Fully counterclockwise (OFF)

Y2:

POSITION	Center the trace on the screen.
VOLTS/CM	10 mV (or 20 mV or 50 mV if necessary)
INPUT switch	AC
TRIG	Y2, +

9. Adjust Y2 input trimmer capacitor C111-2 (÷ 1) for the correct amount of compensation. If you obtain proper compensation, disregard the following lettered steps and proceed to step 10. If you cannot obtain proper compensation, perform the following lettered steps.

   A. Adjust Y2 input trimmer capacitor C111-2 (÷ 1) for the maximum amount of overshoot on the leading edge of the waveform as shown in Part A of Figure 21. This adjustment sets the Y2 input capacitor to minimum capacitance.

   B. Adjust the probe trimmer for the proper amount of compensation.

   C. Disconnect the probe from the Y2 INPUT connector and connect it to the Y1 INPUT connector.

   D. Set the indicated front panel controls as follows:

Y1 POSITION	Center the trace on the screen
Y2 POSITION	Fully counterclockwise (OFF)
TRIG	Y1, +

   E. Adjust the Y1 input trimmer capacitor C111-1 (÷1) for the proper amount of compensation.

10. Set the indicated front panel controls as follows:

Y1:	
POSITION	Center the trace on the screen.
VOLTS/CM	100 mV (or 200 mV or 500 mV if necessary)
Y2:	
POSITION	Fully counterclockwise (OFF)
VOLTS/CM	100 mV (or 200 mV or 500 mV if necessary)
TRIG	Y1, +

11. Connect the probe to the Y1 INPUT connector.

Input Compensation

NOTE: Readjust the 1000 Hz square wave amplitude as necessary throughout the following procedure to increase the display amplitude.

1. Channel Y1: Perform the following lettered steps (A-K). Adjust only the controls and trimmer capacitors marked Y1 or associated with Channel Y1.

   A. Adjust the POSITION control to put the trace in the center of the screen.

   B. Adjust trimmer capacitor C108 (÷ 10) for the proper amount of compensation.

   C. Turn the VOLTS/CM switch to the 1V position (or 2V or 5 V if necessary).

   D. Adjust trimmer capacitor C105 (÷ 100) for the proper amount of compensation.

   E. Turn the VOLTS/CM switch to the 10V position (or 20V if necessary).

   F. Adjust trimmer capacitor C102 (÷ 1000) for the proper amount of compensation. Examine this display carefully as it may be quite small.

   G. Turn the POSITION control fully counterclockwise (OFF) and decrease the amplitude of the 1000 Hz square wave signal.

   H. Turn the TRIG switch to Y2, +.

Disconnect the probe from the Y1 INPUT connector and connect it to the Y2 INPUT connector.

Channel Y2: Perform the previous lettered steps (A-G). Adjust only the controls and trimmer capacitors marked Y2 or associated with Channel Y2.

Disconnect the square wave signal from the Oscilloscope.

Set the indicated front panel controls as follows:

Y1:	
INPUT switch	GND
POSITION	Center the trace on the screen
Y2:	
INPUT switch	GND
POSITION	Fully counterclockwise (OFF)

Proceed to "Touch-Up Adjustments."

TOUCH-UP ADJUSTMENTS

This section of the Manual deals with the final or touch-up adjustments that insure the accuracy of your Oscilloscope. Any time you perform the "Initial Calibration," operate the Oscilloscope for at least 48 hours, and then perform all of the following touch-up adjustments. However, any time you doubt the accuracy of a particular circuit within your calibrated Oscilloscope, make only the appropriate touch-up adjustment.

Allow the Oscilloscope to warm up for at least three hours with the covers on and with the Oscilloscope setting in its normal operating position. Do not stand it on the rear panel to make the touch-up adjustments. Keep it in the normal operating position.

To insure that the adjustments are made under actual operating conditions, remove the appropriate cover only long enough to make each adjustment. Replace the cover immediately after you make each adjustment and allow 5 minutes for the Oscilloscope to stabilize. Then recheck the adjustment.

If you have replaced a component or serviced the Oscilloscope, you must perform the "Initial Calibration" before you make touch-up adjustments.

Touch-Up Sweep Adjustment (time base calibration) — Carefully perform the "Sweep" calibration steps (1-19) starting on Page 28. NOTE: The sweep calibration is affected when the voltage and horizontal amplifier are readjusted.

Touch-Up Vertical Amplifier Gain Adjustment — Carefully perform the "Vertical Amplifier" calibration steps (1-3) on Page 28. NOTE: The vertical calibration is affected when the voltage is readjusted.

Touch-Up Trigger Adjustment — Carefully perform the "Trigger" calibration steps (1-7) on Page 27. This adjustment is not affected by other adjustments.

Touch-Up X-Y Adjustment — Carefully perform the "X-Y" calibration steps (1-8) on Page 30. NOTE: The X-Y calibration is affected when the Y1 vertical amplifier, horizontal gain, or voltage are readjusted.

Touch-Up Sweep Length Adjustment — The SWEEP LENGTH control (R437, on the time base circuit board) can be readjusted as desired (usually for an 11 cm trace) without affecting other adjustments.

IN CASE OF DIFFICULTY

The troubleshooting information for your Oscilloscope is presented as a general troublehooting table and in a series of test charts. If you know that a problem exists in a particular circuit, proceed to the test chart that covers that circuit. However, if your Oscilloscope does not operate for an unknown reason, proceed to "General Troubleshooting" and/or the section entitled "Locating the Problem." Read the following paragraphs carefully before you begin troubleshooting. You should also read the "Circuit Description."

TROUBLESHOOTING PRECAUTIONS AND NOTES

WARNING: The full AC line voltage and high voltage DC is present at several points in the Oscilloscope. Be careful to avoid personal shock when you work on the Oscilloscope. Refer to Figure 23 (in the "Illustration Booklet").

- Be cautious when you test transistors and integrated circuits. Although they have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage and current than other circuit components.
- Be careful so you do not short any terminals to ground when you make voltage measurements. If the probe should slip, for example, and short out a bias or voltage supply point, it may damage one or more components.
- Do not remove any components while the Oscilloscope is turned on.
- When you make repairs to the Oscilloscope make sure you eliminate the cause as well as the effect of the trouble. If, for example, you should find a damaged resistor, be sure you find out what caused the resistor to become damaged. If the cause is not eliminated, the replacement resistor may also become damaged when the Oscilloscope is put back into operation.
- Refer to the "X-Ray Views" and the "Schematic Diagram" to locate the various components.
- Use a high impedance voltmeter to make the specified measurements in this section.

The following symbols and procedures are used in the troubleshooting charts: The numbered Test Charts are in the "Illustration Booklet."

YES — Follow the "YES" arrow when you obtain the proper measurement or condition.

NO — Follow the "NO" arrow when you do not obtain the proper measurement or condition.

≈ — This symbol, "APPROXIMATELY EQUAL TO," before a voltage measurement indicates that this voltage may vary as much as ±20%.

REPEAT TEST # — This means to repeat a particular test after a problem has been located and corrected.

All voltages given in the troubleshooting charts were taken with a nominal line voltage of 120 VAC.

Components are listed in the order in which failure or a problem is most likely to occur.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

GENERAL TROUBLESHOOTING

PROBLEM	POSSIBLE CAUSE
Oscilloscope does not turn on.	1. Line cord not plugged in. 2. Fuse F1. 3. Switch SW3, SW4, or SW5.
Power lamp lights, no trace.	1. Proceed to "Locating the Problem" on Page 40.
Trace is visible, but one channel will not center, or is not visible.	1. Perform DC Balance adjustment. 2. Go to Test Chart #6. 3. Go to Test Chart #11.
Gain factor wrong.	1. Check high voltage (−1700 VDC). 2. Calibrate Oscilloscope.
Gain Factor does not change in proper order.	1. Calibrate the Oscilloscope. 2. Check input attenuator RC networks. 3. Check switched-gain amplifier RC networks.
Bandwidth too low, or rise time excessive.	1. Adjust wire separation to vertical deflection plates in CRT. 2. Adjust high frequency compensation C118 – (1 or 2).
Can not balance a vertical amplifier.	1. Interchange transistors Q101 and Q102 of that channel.

PROBLEM	POSSIBLE CAUSE
Excessive overshoot.	1. Adjust high frequency compensation C118 — (1 or 2).
"Hash" or "grass" appears at low sweep speeds in dual trace operation.	1. Check for chop signal at pin 6 of IC210B. 2. Check Q401, ZD401, and associated circuitry. CAUTION: These components are on the high voltage circuit board.
Oscilloscope does not sweep.	1. Go to Test Chart #10.
Oscilloscope sweeps but does not trigger properly.	1. Adjust DC trigger ZERO control R149-(1 or 2). 2. Go to Test Chart #9.
Oscilloscope triggers but auto-baseline does not function.	1. Check IC205 and associated circuitry. 2. Check IC209.
Sweep out of calibration.	1. Calibrate sweep.
Sweep will not calibrate.	1. Check high voltage (−1700 VDC). 2. Go to Test Chart #10.
Sweep is nonlinear.	1. Check Q203, Q204, Q205, Q206, and associated circuitry.
Time base ranges do not change in proper order.	1. Check TIME/CM switch and associated RC networks.
Trace too long or too short, Oscilloscope calibrated.	1. Perform the "Touch-Up Adjustments" in the "Calibration" section.
Some retrace appears when operating in the high Time/Cm settings when not triggered (auto base line). When triggered on a waveform, no retrace is visible.	This is normal.

PROBLEM	POSSIBLE CAUSE
Oscilloscope does not blank (retrace visible), or does not unblank (no trace).	1. Check pins 14 and 15 of IC203A for blanking signal. 2. Check holes H and F on the high voltage circuit board for the blanking signal. CAUTION: The blanking circuit operates at 1700 volts below ground potential. If you suspect a defective component, remove and check the component. Do not check it on the circuit board. If your probe slips, a number of components could be damaged.
Calibrator does not function.	1. Check Q209, IC208, and associated circuitry.
X-Y not calibrated.	1. Adjust X-Y CAL control R258.
No "X" and/or "Y" position control in X-Y.	1. Go to Test Chart #12.
Oscilloscope will not unblank in X-Y, unblanks in normal operation.	1. Go to Test Chart #12.
No "X" deflection in External X operation.	1. Check Q207, Q208, and associated circuitry.
No "Y" deflection in External X operation.	1. Check for normal "Y" channel operation.
Only one "Y" channel functions in External X operation.	1. Check for chop signal at pin 8 of IC211. 2. Check Q120, Q121, and associated circuitry. 3. Check diode switch.

LOCATING THE PROBLEM

This test will help you isolate the problem to a particular circuit. Then, with the aid of the remaining charts, you can locate and correct the problem.

1. Connect the line cord plug to an AC outlet.

2. Turn on the Oscilloscope.

3. Set the front panel controls as follows before each test:

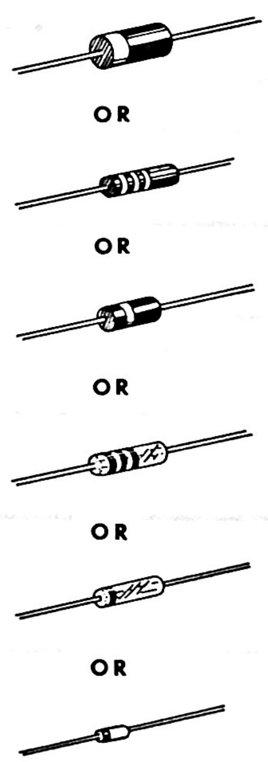
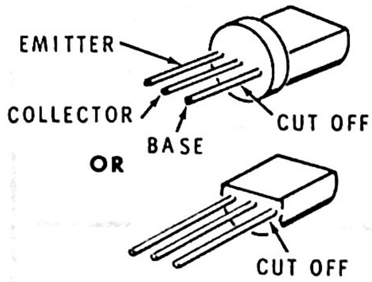
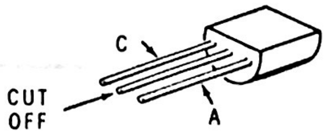
INTENSITY	Center of rotation
FOCUS	Center of rotation
Y1:	
INPUT switch	GND
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
POSITION	Center of rotation
Y2:	
INPUT switch	GND
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
POSITION	Fully counterclockwise (OFF)
OTHER:	
TRIG MODE	AC
HORIZ POS	Center of rotation
TRIG	Y1, +
LEVEL	Center of rotation, and pushed in (AUTO)
TIME/CM	EXT
VARIABLE	Fully clockwise (CAL) and pushed in

4. Perform the power supply tests (#1 through #5, in the "Illustration Booklet") to verify the operation of the power supplies before proceeding. The power supplies must operate properly before you attempt any further troubleshooting.

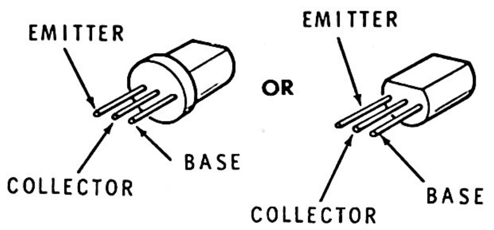
5. Perform the steps as directed in the "Trouble Locator Chart" (in the "Illustration Booklet").

IDENTIFICATION CHARTS

DIODES

DIODES	HEATH PART NUMBER	MAY BE REPLACED BY	DESCRIPTION	BASING DIAGRAM
ZD203, ZD204, ZD211, ZD210	56-16	IN751 (VIOLET-GREEN-BROWN)	ZENER DIODE 20mA, 5.1V	NOTE: HEATH PART NUMBERS ARE STAMPED ON MOST DIODES. 
D103-1, D103-2, D104-1, D104-2, D106-1, D106-2, D107-1, D107-2, D108-1, D108-2, D109-1, D109-2, D110-1, D110-2, D205, D206, D207, D208, D406	56-56	IN4149	DIODE 10mA, 75V	
ZD105-1, ZD105-2	56-50	DO-7	ZENER DIODE 70mA, 3.6V	
ZD209	56-59	IN750A	ZENER DIODE 20mA, 4.7V	
ZD401, ZD403	56-68	ZVR-68	ZENER DIODE 7mA, 68V	
ZD313, ZD314	56-616	IN5232	ZENER DIODE 1mA, 5.6V	
D301, D302, D303, D304, D305, D306, D307, D308, D309, D310, D311, D312, D402	57-27	IN2071	DIODE 1A, 600V	
D404, D405	57-56	SCM-30	DIODE 10mA, 3 kV	
ZD201, ZD202, ZD212, ZD213	417-118	2N3393	TRANSISTOR USED AS DIODE	
D101-1, D101-2, D102-1, D102-2	417-854	SF50077	DIODE	

TRANSISTORS

<table>
<tr><th>TRANSISTORS</th><th>HEATH PART NUMBER</th><th>MAY BE REPLACED BY</th><th>BASING DIAGRAM</th></tr>
<tr><td>Q304</td><td>417-118</td><td>2N3393</td><td rowspan="2">
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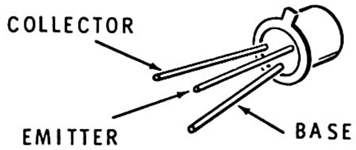
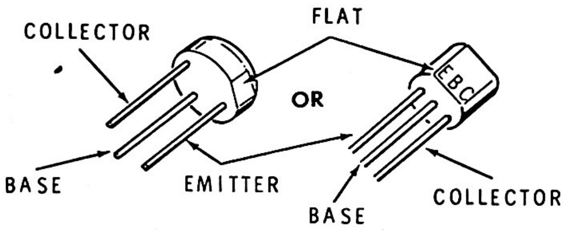
<tr><td>Q104-1, Q104-2, Q208, Q306,</td><td>417-201</td><td>X29A829</td></tr>
<tr><td>Q111, Q112,</td><td>417-100</td><td>36632</td><td rowspan="2">
</td></tr>
<tr><td>Q203, Q206,</td><td>417-154</td><td>2N2369</td></tr>
<tr><td>Q305</td><td>417-234</td><td>2N3638A</td><td rowspan="3">
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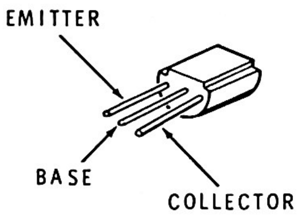
<tr><td>Q210, Q211, Q216,</td><td>417-235</td><td>2N4121</td></tr>
<tr><td>Q212, Q213,</td><td>417-237</td><td>SE6020</td></tr>
<tr><td>Q105-1, Q105-2, Q106-1, Q106-2</td><td>417-292</td><td>2N5771</td><td rowspan="2">
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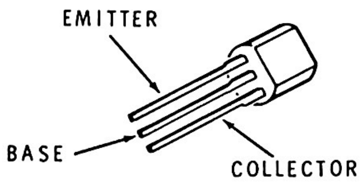
<tr><td>Q109-1, Q109-2, Q110-1, Q110-2, Q115-1, Q115-2, Q116-1, Q116-2, Q117-1, Q117-2, Q209</td><td>417-293</td><td>2N5770</td></tr>
<tr><td>Q103-1, Q103-2, Q107-1, Q107-2, Q108-1, Q108-2, Q118-1, Q118-2, Q119-1, Q119-2, Q120, Q121, Q207.</td><td>417-801</td><td>MPSA20</td><td rowspan="2">
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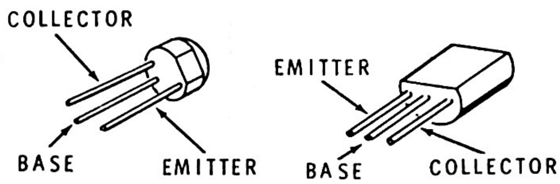
<tr><td>Q401</td><td>417-811</td><td>MPSL01</td></tr>
<tr><td>Q402, Q403</td><td>417-805</td><td>2N4889</td><td>
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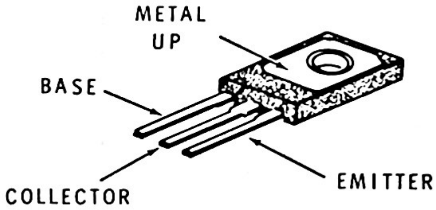
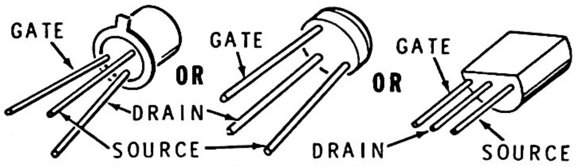
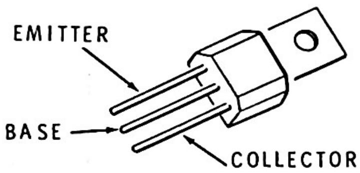
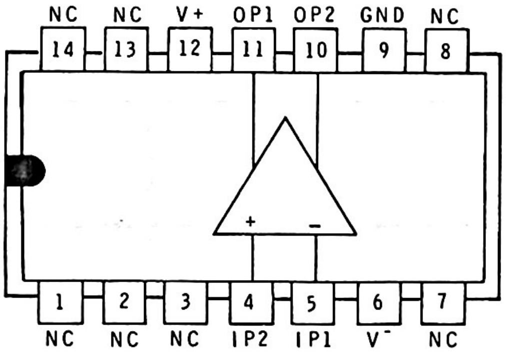
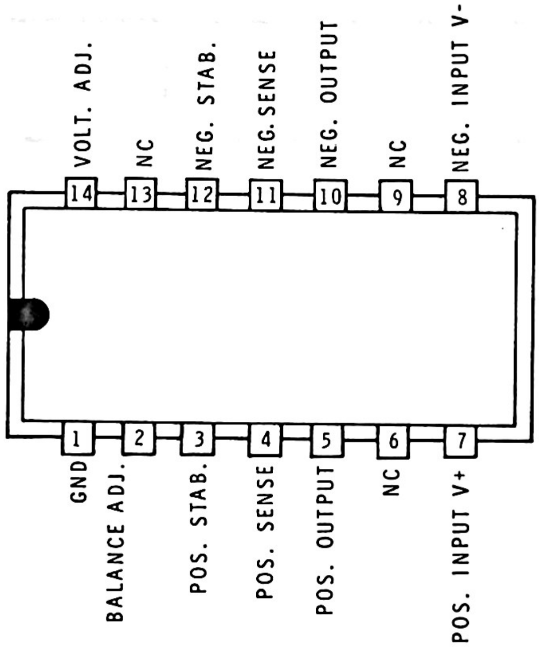
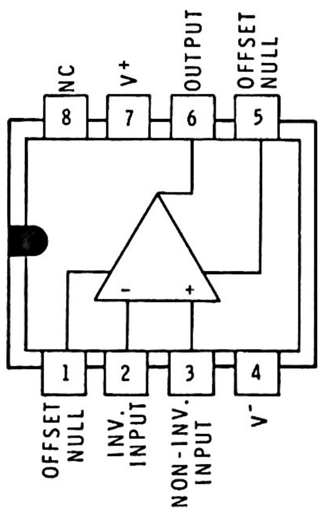
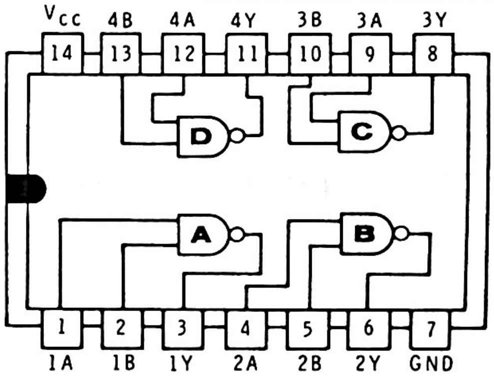
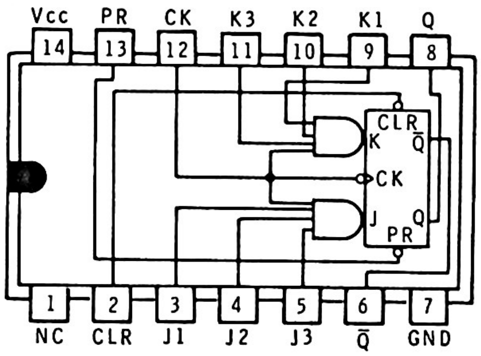
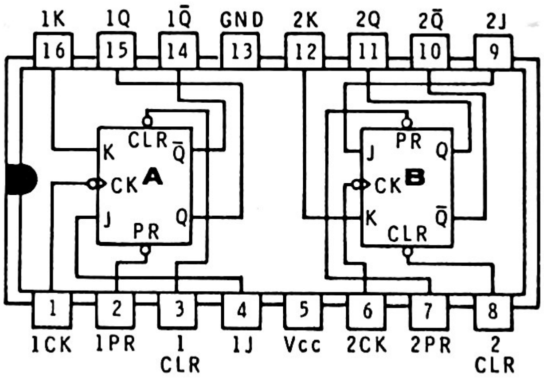
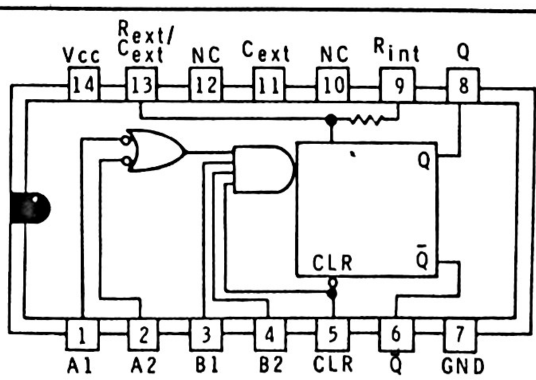
Transistors (cont'd.)

TRANSISTORS	HEATH PART NUMBER	MAY BE REPLACED BY	BASING DIAGRAM
Q302	417-818	MJE 181	
Q301	417-819	MJE171	
Q101,1, Q101-2, Q102-1, Q102-2, Q201, Q202, Q204, Q205	417-828	E304	
Q113, Q114, Q214, Q215, Q404, Q405, Q406	417-834	MPSU10	
Q303	417-224	MPSU05	

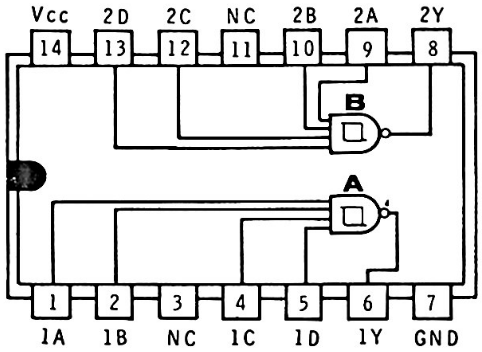
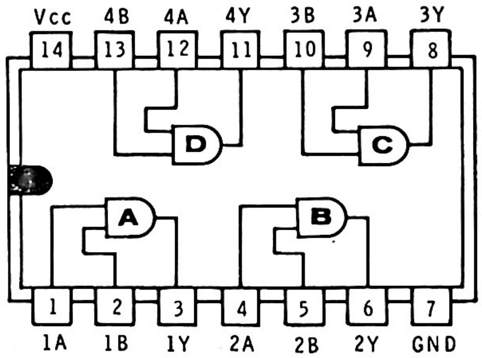
INTEGRATED CIRCUITS

INTEGRATED CIRCUITS	HEATH PART NUMBER	MAY BE REPLACED BY	DESCRIPTION	LEAD CONFIGURATION (TOP VIEW)
IC201	442-50	µ760	DIFFERENTIAL COMPARATOR	
IC301	442-65	SG4501N	±15 VOLT REGULATOR	
IC401	442-22	N5741V	OPERATIONAL AMPLIFIER	

Integrated Circuits (cont'd.)

INTEGRATED CIRCUITS	HEATH PART NUMBER	MAY BE REPLACED BY	DESCRIPTION	LEAD CONFIGURATION (TOP VIEW)
IC202, IC204, IC208	443-1	SN7400N	QUADRUPLE 2-INPUT POSITIVE-NAND GATES	
IC211	443-4	SN7472N	AND-GATED J-K MASTER-SLAVE FLIP-FLOPS WITH PRESET AND CLEAR	
IC203	443-16	SN7476N	DUAL J-K FLIP-FLOPS WITH PRESET AND CLEAR	
IC205, IC206	443-23	SN74122N	RETRIGGERABLE MONOSTABLE MULTIVIBRATORS WITH CLEAR	

Integrated Circuits (cont'd.)

INTEGRATED CIRCUITS	HEATH PART NUMBER	MAY BE REPLACED BY	DESCRIPTION	LEAD CONFIGURATION (TOP VIEW)
IC207	443-44	SN7413N	DUAL 4-INPUT POSITIVE-NAND SCHMITT TRIGGERS	
IC209, IC210	443-45	SN7408N	QUADRUPLE 2-INPUT POSITIVE-AND GATES	

CUSTOMER SERVICE

REPLACEMENT PARTS

Please provide complete information when you request replacements from either the factory or Heath Electronic Centers. Be certain to include the **HEATH** part number exactly as it appears in the parts list.

Replacement parts are maintained specifically to repair Heath products. Parts sales for other reasons will be declined.

ORDERING FROM THE FACTORY

Print all of the information requested on the parts order form furnished with this product and mail it to Heath. For telephone orders (parts only) dial 616 982-3571. If you are unable to locate an order form, write us a letter or card including:

- Heath part number.
- Model number.
- Date of purchase.
- Location purchased or invoice number.
- Nature of the defect.
- Your payment or authorization for COD shipment of parts not covered by warranty.

Mail letters to: Heath Company
Benton Harbor
MI 49022
Attn: Parts Replacement

Retain original parts until you receive replacements. Parts that should be returned to the factory will be listed on your packing slip.

OBTAINING REPLACEMENTS FROM HEATH ELECTRONIC CENTERS

For your convenience, "over the counter" replacement parts are available from the Heath Electronic Centers listed in your catalog. Be sure to bring in the original part and purchase invoice when you request a warranty replacement from a Heath Electronic Center.

TECHNICAL CONSULTATION

Need help with your kit? — Self-Service? — Construction? — Operation? — Call or write for assistance. you'll find our Technical Consultants eager to help with just about any technical problem except "customizing" for unique applications.

The effectiveness of our consultation service depends on the information you furnish. Be sure to tell us:

- The Model number and Series number from the blue and white label.
- The date of purchase.
- An exact description of the difficulty.
- Everything you have done in attempting to correct the problem.

Also include switch positions, connections to other units, operating procedures, voltage readings, and any other information you think might be helpful.

Please do not send parts for testing, unless this is specifically requested by our Consultants.

Hints: Telephone traffic is lightest at midweek — please be sure your Manual and notes are on hand when you call.

Heathkit Electronic Center facilities are also available for telephone or "walk-in" personal assistance.

REPAIR SERVICE

Service facilities are available, if they are needed, to repair your completed kit. (Kits that have been modified, soldered with paste flux or acid core solder, cannot be accepted for repair.)

If it is convenient, personally deliver your kit to a Heathkit Electronic Center. For warranty parts replacement, supply a copy of the invoice or sales slip.

If you prefer to ship your kit to the factory, attach a letter containing the following information directly to the unit:

- Your name and address.
- Date of purchase and invoice number.
- Copies of all correspondence relevant to the service of the kit.
- A brief description of the difficulty.
- Authorization to return your kit COD for the service and shipping charges. (This will reduce the possibility of delay.)

Check the equipment to see that all screws and parts are secured. (Do not include any wooden cabinets or color television picture tubes, as these are easily damaged in shipment. Do not include the kit Manual.) Place the equipment in a strong carton with at least THREE INCHES of *resilient* packing material (shredded paper, excelsior, etc.) on all sides. Use additional packing material where there are protrusions (control sticks, large knobs, etc.). If the unit weighs over 15 lbs., place this carton in another one with 3/4" of packing material between the two.

Seal the carton with reinforced gummed tape, tie it with a strong cord, and mark it "Fragile" on at least two sides. Remember, the carrier will not accept liability for shipping damage if the unit is insufficiently packed. Ship by prepaid express, United Parcel Service, or insured Parcel Post to:

Heath Company
Service Department
Benton Harbor, Michigan 49022

HEATH
Schlumberger

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